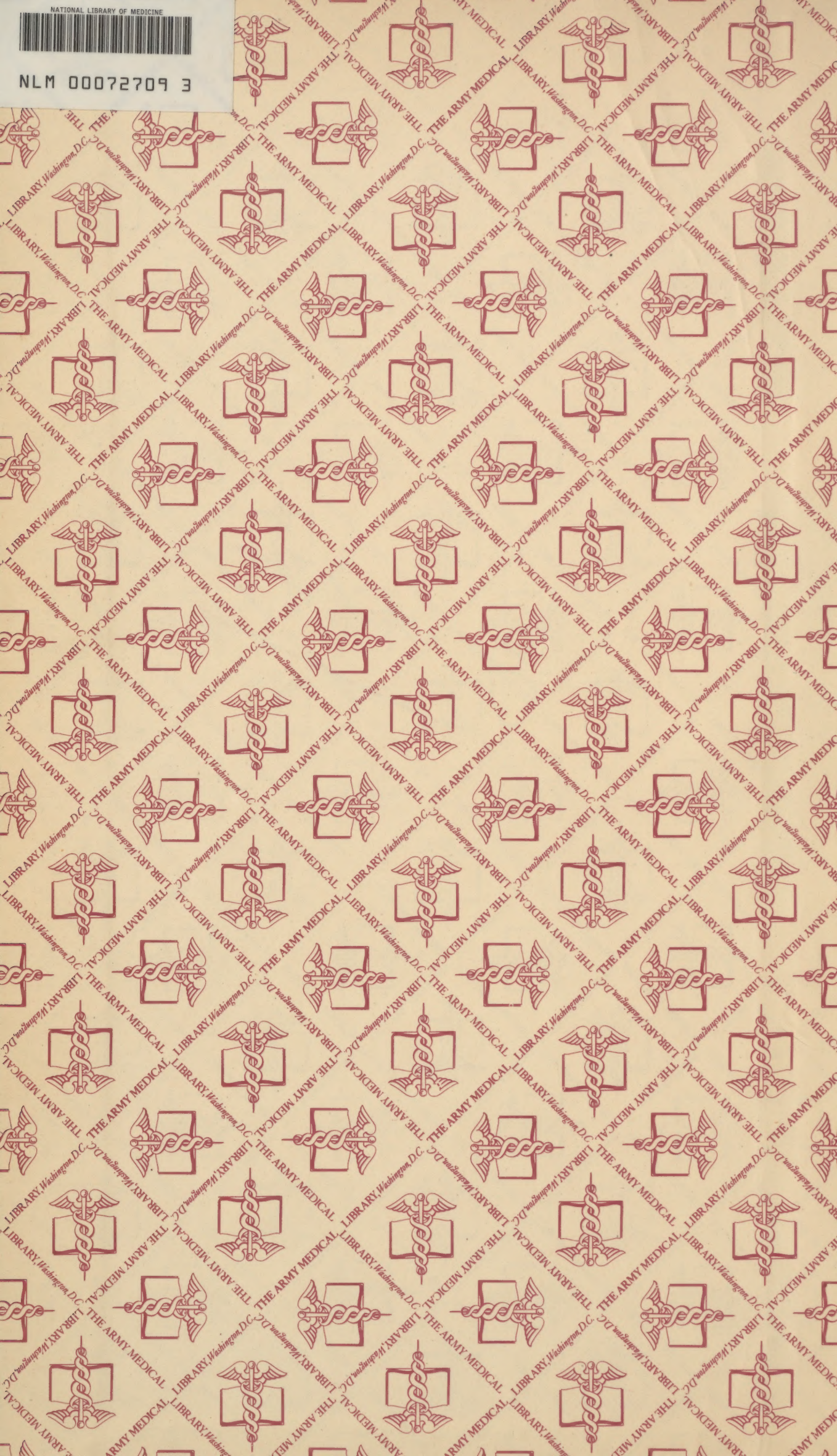
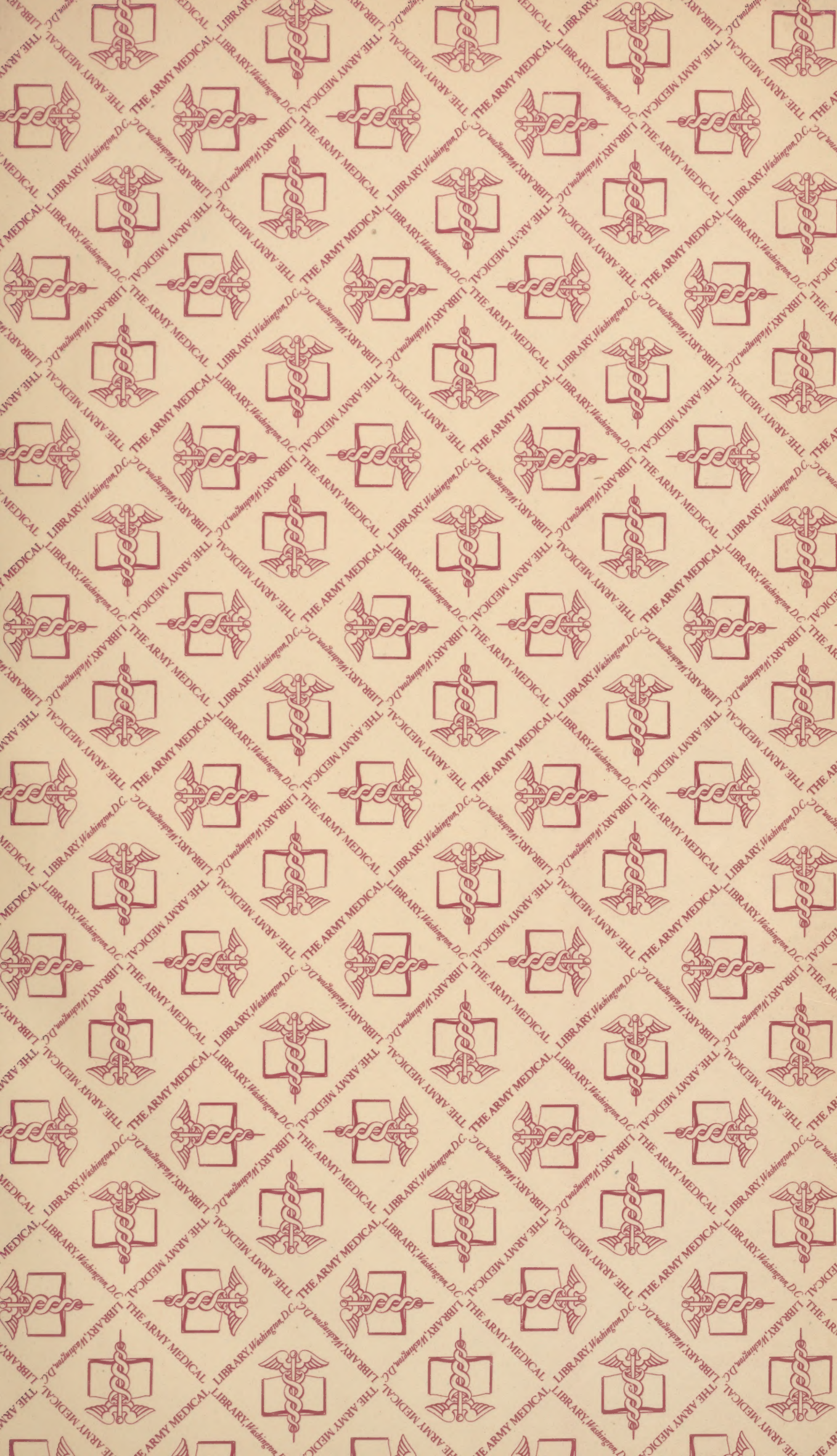


NLM 00072709 3

















## CHAPTER VII.

### The marrow nailing of compound fractures, fresh gunshot fractures and infected fractures.

#### A. The compound fracture.

The per primam healing of a wound is much more advantageous than a healing per secundam and it seems to be worthwhile to begin with this fact when dealing with the treatment of compound fractures, for compound fractures are primarily wounds. The accompanying table published by GAZA is a good demonstration of the difference in healing process.

Consequently we must try to achieve a prima intentio healing in all compound fractures. The question how to attain this was answered a long time ago by FRIEDRICH's classical tests which dealt with the following problems:

- (1) How long does it take for the bacteria contained in the infected material which has entered the wound to develop, and when does the first symptom of infection appear?
- (2) For which period of time is the wound infection a process of local significance?

We have to deal with the problem of the period of incubation of the wound infection. In FRIEDRICH's tests the bacteria germinated during the first 6-8 hours. Only after that time may these germs be demonstrated in the more deeply located muscle tissue and in the lymph channels.

FRIEDRICH asks the following question: Is it possible to protect the test animal against a general infection within the first six hours? This question was answered in the affirmative, but all means of disinfection proved to be without any effect. Only by a thorough freshening of the wound for 1-2 mm. into the sound tissue was it possible to prevent an infection with certainty within the first six hours.

Success was uncertain between the sixth and eighth hours. In all cases in which an infection already existed there was only one effective means: to keep the infected wound open. Also in this case all disinfectants proved to be absolutely useless. According to FRIEDRICH the excision must be made with the knife and not with the scissors because they touch the sound and the questionably infected areas as well. The wound must not be touched by the fingers or probes.

The necrotic tissue must also be removed. We know the best conditions for growth exist there for all germs because the protective ferments of the body cannot get there so easily. Foreign bodies must also be removed. The surface, pockets and slots of foreign bodies frequently are the seats of the germs and therefore we do not want to insert foreign bodies into the wound.



WE WH  
185 390  
K96m FLX3737P  
1949 Project 2, fol. 9  
v. 4



Difference of the healing process per primam and per secundam (after GAZA)

Consequences of injury	Primary healing of the wound after excision and suture	Healing per secundam or per granulationem
1. Duration of the healing process	skin wounds 5-8 days. Tendons, bones, etc. a couple of weeks	lasts for weeks and even months, frequently a surgical interference becomes necessary
2. Wound-necrosis suture-ligature	aseptic healing-in or resorption	demarcation by suppuration of the wound
3. Accidental germs in the wound	occur in small numbers only. Most of the germs were removed by the excision. Elimination of the rest by the bactericidal forces of the body	primary wound infection, localized or spreading. Secondary infection by infiltrating bacilli. Quiescent infection causing delayed damage
4. Metabolism	short dissimilative phase (destruction), short assimilative phase (construction); which develop together early, histolytic processes predominate with only slow decomposition of the tissue. Small quantities of wound secretum which are resorbed by the body.	long dissimilative phase (suppuration of the wound) and delayed assimilative phase. In most cases excessive formations of scars after the detachment of large areas of tissue. Atypical and unrestrained processes of decomposition with the formation of toxic products of decomposition which is complicated because of the participation of bactericidal ferments. Demarcation of the wound necrosis (Necrolysis). Moderate, constant effusion of pus and wound secretum. Loss of large quantities of protein in the wound secretum
5. Restoration of the function	quick and frequently complete restoration of the function in case of wounds of the muscles, sinews, skin, vessels, nerves, etc. Life is saved in cases of particularly endangered or vital organs (vessels, peritoneum, pleura, bowels, brain)	very slow, and frequently only partial restoration of the function which may even fail to appear. In case of a damage of the vital or particularly endangered organs frequently fatal termination
6. Social consequences	quick restoration of ability to work which is of utmost importance for the family as well as for the community	long lasting inability to work. Loss of valuable man-power, pensions, etc.



The skin above the wound must be sutured and we must take care that there is no tension on the suture because otherwise the blood supply of the wound would be impaired and with it also the defense force. If necessary, additional incisions must be made to relieve the tension.

This method proved best in innumerable cases of our daily practice and particularly in the treatment of compound fractures.

When taking all this into consideration it seems to be very dangerous to treat a compound fracture with the marrow nail method. From the surgical point of view it might even be considered to be a nonsense to insert such a large foreign body into a wound which is already highly endangered by infection. Despite the greatest care, there also exists the danger that dirty particles loaded with germs and located deeply in the wound are transmitted to the marrow cavity of the proximal fragment by means of the marrow nail. On the other hand it must be taken into consideration that in case of the marrow nail we have to deal with a tube which may act like a drain and that in this way eventually developing secretion may drain off immediately along the nail. It is possible that the increased antibacterial force of the marrow tissue mentioned in chapter IV is also effective in this case. One thing is certain, however, that there is no other method with which it is possible to immobilize the fragments so absolutely as with the marrow nail method. The best means to prevent and to treat an infection is immobilization. There is no doubt that in this connection constant movements and shifting amounting to only fractions of millimeters occur which by no means can be eliminated with the best fitting plaster cast. They are due to constant muscle actions and thus these disadvantageous effects cannot be prevented by using the traction method either.

#### Animal tests by the author.

The above mentioned considerations seem to justify treating compound fractures with the marrow nail method. In 1939 the author had made corresponding tests on dogs and published the results. Those tests were very simple. The fur of the test animal was neither shaved nor disinfected and the skin of the thigh at the lateral aspect was separated by means of a scalpel. The musculature was bluntly separated and the bone was broken by means of a chisel. After that the fur was driven into the wound so that it touched the fragments and the typical marrow nail operation was performed. Finally the wound was sutured. In all cases marked infections developed which made it necessary to remove the sutures a couple of days later. Marked suppurative secretions were observed. In all cases excellent results were obtained. The fractures came to a good healing and the formation of callus was excellent. The nails were removed 4-6 weeks later before the suppurative secretion had ceased. Sequestra were not observed. Two to



three weeks later the wounds had cicatrised. These results were rather encouraging but it was not possible to apply those principles to humans. In the test cases we did not have to deal with marked necrosis of the soft parts and of the bones in contrast to the conditions prevailing in accidental wounds. Therefore the author decided to apply the marrow nail method to the treatment of compound fractures in humans only some time later.

The marrow nailing of compound fractures in humans.

W. EHRLICH was the first to apply the marrow nail method to the treatment of compound fractures in humans. His procedure was as follows: The injured damaged spot was thoroughly excised and all contused particles of the musculature were removed by means of a scalpel. If necessary a second incision must be made in order to be able to set the fragments as accurately as possible. After that marrow nailing (as described in chapter VI B) starts.

In some oblique fractures EHRLICH made additional wire sutures. Also in other cases of compound fractures EHRLICH applied wire loops and wire sutures. His results were excellent as is shown by the following table:

COMPOUND FRACTURES ACCORDING TO EHRLICH:

Kind of treatment	Total	Seriousness of injury				Duration of healing			Healing		
		I	II	III	IV	high	low	med.	prim.	p.gran.	sec.
Wire loop or wire suture	34	10	7	15	2	238	35	101.3	12	14	8
extension bandage and/or plaster cast	33	18	10	5	1	320	30	98.2	12	14	7
nailing operation accordg.to KUENTSCHER	53	33	9	13	1	216	37	67.7	27	16	10

Comment: The Roman numbers given above indicate the seriousness of the injury: I - small perforating wounds with serious damage to the bone. II - large wound of the soft parts with projecting bone. III - large wound of the soft parts with a considerable comminution of the bone and the tissue. IV - most serious cases (almost fatal).

We must differentiate between a healing per granulationem and a secondary healing because he kept the penetrating wounds either entirely or partly open or because additional incisions were made. It is a matter of course that the wounds which were not closed by means of a suture did not heal primarily. The ca-



ses with a secondary healing are understood to be those cases in which a suppuration occurred which extended to the fracture site either with or without a late formation of sequestra. The time referring to the duration of healing in the above table is understood to be that period of time after the lapse of which the fracture became firm and it does not mean the time until the patient was released from the hospital.

Fatal terminations or amputations were not observed. The above summary proves that a marked difference does not exist in connection with the cases which came to a secondary healing. This number is 23.5% for the cases in which a wire loop had to be applied, 21.2% with the traction bandage and 19.9% with the marrow nail method. The existing differences are within the margin of error. It must be pointed out, however, that the number of serious cases treated with usual traction bandage and/or plaster cast is much smaller. In the compound fractures treated with the marrow nail we have to deal with 9 thigh fractures, 38 leg fractures, and 6 fractures of the arm above the elbow. EHRLICH points out that the treatment is considerably facilitated if an infection occurs when a marrow nail is used. Due to the fact that the fracture site is stable, the surgeon is in a position to look for every suppuration and to bring the limb into a position which is most useful for the draining off of the pus. According to EHRLICH's experiences, danger of infection of the marrow does not exist in compound fractures treated with the marrow nail method. He is of the opinion that his results could hardly be obtained with any other method. He warns, however, against treating those cases with the nail method with which a third fragment must be slipped over the nail (V) because in most of the cases of that kind either the larger part or the entire third fragment were detached.

In connection with the excellent results obtained by EHRLICH, I would like to point to the fact that most of the operations were made on miners and it is a matter of course that infections accompanying coal dust are not as dangerous as an infection accompanying earth.

According to a summary published by GRIESSMANN and SCHUETTEMEYER there were 24 compound fractures out of a total of 155 cases of marrow nail operations treated at the Kiel clinic from January 1st, 1944 to May 1st, 1946, i. e. 7 thigh fractures, 15 leg fractures and 2 forearm fractures. The following table shows the healing process:

Healing of nailed compound fractures at the Kiel clinic:  
1944 - 1946

	per primam	per secundam	total	exitus
thigh	4	3	7	-
leg	7	8	15	2
forearm	-	2	2	-

The above mentioned 4 thigh fractures which healed per primam did in no way differ from the results obtained with the marrow nailing of simple fractures as to course of the



healing, stay in the hospital and the period of time after which first weight bearing was possible. All patients were able to get up early and to leave the clinic at an early date.

In the fifth case we had to deal with a fracture in the lower third of the thigh and a complicated wound just above the patella. Due to the fact that the nail did not find sufficient hold because the fracture was so near the joint (see chapter V) and an additional pelvis cast was applied in order to immobilize the wound. At the fracture site, which came to a primary healing, considerable cicatrization of the soft parts with a considerable limitation of the flexibility of the knee joint was observed. In the 6th and 7th cases we had to deal with 5 and 6 year old children, in which an infection occurred after the marrow nailing. The marrow nailing had been made after primary wound treatment. In both cases typical ring sequestra were observed three months after the operation (see chapter IV). There existed a marked periosteal formation of callus. The marrow nails were removed after a lapse of four months and both fractures came to a good healing with the fragments in good position after the removal of the sequestra. There existed neither an impediment of the joints nor was there any muscle atrophy.

In the 15 cases of leg fractures we used double nails, nails with inclined planes and turn spread nails (see chapter V). The shape and the location of the fractures are demonstrated in the following statistics by GRIESSMANN and SCHUETTEMEYER:

#### Summary

15 cases of compound leg fractures treated at the Kiel clinic from 1944 - 1946 according to GRIESSMANN and SCHUETTEMEYER:

Compound fractures in the leg:						Location and kind of fracture central third:					
15						7					
Transverse fractures:						Oblique fractures:					
7						0					
Double nail		incl. plane		turn-spr. nail		double nail		incl. plane		turn-spr. nail	
7		0		0		0		0		0	
+	Ø	+	Ø	+	Ø	+	Ø	+	Ø	+	Ø
6	1	-	-	-	-	-	-	-	-	-	-
Lower third: 7											
Transverse fractures:						Oblique fractures:				Double fractures:	
3						4				1	
Double nail		incl. plane		turn-spr. nail		double nail		turn-spr. nail		incl. plane	
1		2		0		1		2		1	
+	Ø	+	Ø	+	Ø	+	Ø	+	Ø	+	Ø
-	1	2	-	-	-	1	-	2	1	-	-

Key: + = stable  
Ø = unstable



With only one exception good healing was obtained in all fractures mentioned in the above statistics. In seven cases healing per primam was observed. In six cases an infection of the compound wound occurred and in addition in two cases an infection of the nail insertion site was observed. In one case it was not possible to apply a primary wound suture, because the wound was located in an extended area of scars. In a second case a covering of the 21 cm. long wound was only possible by additional incisions. In this case we had to deal with a 45 year old patient whose wound suppurated, but fever was not observed. Three weeks later he suddenly died of lung embolism. A second fatal termination occurred in a 44 year old patient who had been injured during an air raid and was brought to the clinic in a most serious condition of shock. Therefore only a wire extension at the calcaneus was applied. After a lapse of fourteen days the condition of the patient was much better and the fever, which during the first days was between 37 and 38°C, had subsided. In the wound several necrotic areas were observed. The fragments were in bad position and so we decided to nail the fracture. This operation lasted only a few minutes. Immediately after the operation a most serious collapse of the general circulation occurred and 48 hours later the patient died. An autopsy could not be made but there is no doubt that the operation was made too early.

In all the other cases the developing infections were easily counteracted by exposing the wounds or by the use of small counter-incisions. So in no case was the picture of a bone suppuration observed. In only four cases did a curettage of the fistula have to be made 6 weeks later during which granulated tissue and small sequestra were removed at the same time. In only one case did a walking cast have to be applied for a period of four weeks. The above mentioned patient, in which a stable union of the fragments could not be achieved, had to stay in the hospital for nine months because of a long lasting formation of fistulae and a delayed healing process.

In all the other cases the period of hospitalization did not last longer on an average than with simple fractures.

In compound fractures (except those with long lasting infections and delayed healing of the bone) the ability to work was restored at about the same time as in simple fractures.

In one case of a forearm fracture the ulna was nailed and a long lasting suppuration was observed. This case could not be observed until a healing was achieved because the patient had to be released from the hospital before that time. In the other case we had to deal with a defect gunshot fracture of the ulna with a complicated injury of soft parts the size of a hand. The patient was immediately nailed and we expected a secondary healing of the wound (see chapter VII B). The wound came to a quick healing. The hospitalization lasted only two days and the patient was treated ambulatorily. The four centimeter long defect of the ulna was amazingly quickly united by a small bone bridge. The patient was able to resume working at an early date with the



nail in place. Thus symptoms of reconstruction were observed in the bone piece and finally a pseudarthrosis occurred. This case is illustrated in chapter III.

C. HAEBLER has reported 15 cases of compound fractures which were all treated with the marrow nail within the 8 hour limit. Twelve cases healed without infection, including two cases of leg fractures with serious damage of the soft parts. The course of a leg fracture with a small perforating wound was very interesting.

"The wound was excised and sutured and a drain inserted into the calf of the leg which was removed 2 days later because the temperature of the patient was normal. The wounds came to a primary healing and consequently the patient was able to get up 20 days later and he resumed working after a lapse of four weeks. Fourteen days after that he complained about drawing pains in the leg and at the scar without any clinical symptoms. After his confinement to bed the pains persisted and 8 days later a swelling of the wound was observed. A dark serous liquid was drained off which was sterile bacteriologically. Some time later the drainage became suppurative and rough bone was observed. The wound continued fistulating and three weeks later a suppuration of the nail insertion site was observed. The fistulae persisted and a small sequestrum was cast off at the fracture site. After the fracture seemed to be healed from the roentgenological point of view the double nail was removed 14 weeks later and after that the fistulae subsided. Between the two nails thick pus was observed. The X-ray reveals that the fracture of the fibula had already bridged over by callus and consequently the fragments could not be pressed together any further. The nail did not forge a stable union with the bone anymore, which is readily recognized by the rarefactions at the nail tips which are due to the mechanical conditions. During the process of subjecting the limb to weight bearing slight wobbling movements of the fragments occur which favor the growing of the germs which had been inactive."

Previously BOEHLER has opposed the osteosynthesis in fresh compound fractures because the fragments must be exposed widely as for instance in the cases in which Lane's plates are used. A further reason is that so far an absolute uninterrupted immobilization of the limb could not be achieved. Due to the fact that the conditions are quite different in marrow nailings BOEHLER recommends this method for the treatment of compound fractures. In comminuted fractures near the joint ends and in all fractures with a long spiral fragment he uses two or three additional wire loops because in these cases a sufficient immobilization cannot be obtained with the nail.



The marrow nailing of compound leg fractures did not prove to be useful. The danger of an osteomyelitis exists and in general the formation of callus is delayed. Therefore in these cases, as well as in compound fractures of the arm and the arm above the elbow, he prefers the application of a wire suture or a wire loop.

These unfavorable experiences in the leg may be explained by the fact that in many cases it is not possible to obtain a true "stable osteosynthesis" with the usual spread nail (see chapter V). As proved by the summary published by the Kiel clinic even in compound transverse fractures in the central third an "absolutely stable osteosynthesis" could not be obtained.

Besides the cases of gunshot fractures to be dealt with in the following chapter the author has so far nailed only four compound fractures: four leg fractures, three of which were due to bomb splinters. All cases came to a good healing with the exception of one case in which we had to deal with a minor suppuration at the nail insertion site.

The clinical experiences made with the marrow nailing of compound fractures may be summarized as follows:

(1) It is possible to nail compound fractures and the above mentioned theoretical objections as to the insertion of such a large foreign body do not exist in reality. This seems to be due to the material we used for the construction of the nail. It does not dissolve and does not cause necrosis. On its smooth surface bacteria do not find any hold.

(2) The effect of the marrow nail against the developing of infection is due to the absolute stable union of the fragments. This effect, however, is of no importance as soon as it is not possible to obtain a "stable osteosynthesis".

(3) If the wound comes to a primary healing the advantages of the marrow nailing are the same as in the nailing of simple fractures. Due to the fact that wounds of the bone and soft parts can be better immobilized than with any other method primary healing will more frequently be observed. The indication for the use of the marrow nail in compound fractures must be very strict. The surgeon has to ask the question whether FRIEDRICH's 8 hour limit is already passed and whether or not according to the shape of the fracture a true "stable osteosynthesis" can be obtained. In this connection I would like to mention that in case of a leg fracture in the lower third a special nail must be used. It is a matter of course that a constant clinical observation for the post-operative period must be certain.

In case of a developing infection the marrow nail method has the following advantages:

(1) The fracture is ideally fixed so that an infection cannot spread so easily to the bone. If, however, the bone is also involved the fixation will even in this case be very advantageous. It is a matter of course that the wounds must immediately be widely opened and at the same time also the nail insertion site. In this way the pus may drain off along the groove of the nail. This means that the fracture is drained from within.



(2) The extremity is readily approachable from all sides so that any eventually developing abscesses and phlegmons may be detected and treated at an early date.

The course of the infection in marrow nailed fractures was dealt with in chapter IV. Let me give here another short summary:

1. A wandering of the suppuration along the nail is quite possible. It will, however, not spread to the bone but only involve the marrow. Even after a lapse of weeks such a progressive inflammation at the nail insertion site may lead to a formation of abscesses below the primarily healed operation wound.

2. Sometimes ring sequestra are observed. This does not mean, however, that the fragments cannot be bridged over by bone. In all cases of that kind we observed a particularly strong formation of callus. In most of the cases those sequestra can easily be removed through the opening of the fistula during the extraction of the nail.

During the marrow nail operation itself FRIEDRICH's wound excision should be done with special care. The process of nailing should also be done as conservatively as possible. If the wounds are small the operation should be done under X-ray control. As soon however, as difficulties are encountered with the reduction the wound should be opened so that the reduction can be made under direct vision. This will be better than to try to bring the fragments in good position by using strong forces. The conservation of the periosteum in this case is much more important than with osteotomy (see chapter VI), because in this case the danger of infection is much greater.

If a suture of the wound is not possible because the defects of the skin are too extended, a thorough wound excision is required and the wound and the nail insertion site as well must be kept wide open. Corrective sutures should be avoided. If necessary, some time later a secondary suture can be made. The nail insertion site should also be kept wide open.

Due to the stable nail osteosynthesis of a compound fracture the fracture is so to say eliminated and we have to deal only with the treatment of the wound of the soft parts. The limb may rest on a splint. A plaster cast should, if possible, not be applied in order to keep the limb accessible. Even in those cases in which for instance the joint is endangered the application of a cast may in one case or the other be avoidable.

In long lasting, intense suppurations the former "stable osteosynthesis" will become loose because of a resorption of the bone round the nail. In such a case an additional plaster cast is required if one does not prefer to replace the nail by a thicker nail. Examples of this kind are given at the end of this chapter.

Just as in simple fractures, the nail must be kept in place until the callus is absolutely stable. The nail is



often blamed for long lasting serious suppurations but this is not correct. Only in those cases in which the smooth surface of the nail is destroyed by rust, which is often observed with double nails, must the nail be blamed for the suppuration, which, however is only slight. More marked suppurations are always due to sequestra, abscesses or phlegmons. In these cases, however, the nail acts as a drain and as soon as we remove the nail we also remove the drain. Furthermore we must take into consideration that with the extraction of the nail the fracture loses its stability which at the same time means a favoring of the infection. Also in those cases in which only a slight formation of callus is observed, the nail is blamed for that but those people forget the damaging effect of the infection upon the formation of callus (see chapter IV). In such a case the nail should be kept in place. According to MAATZ the nail is the best means for the bony bridging over of the fracture cleft.

In any case it is wrong to extract the nail before an absolutely stable formation of callus is obtained. In no case is an infection an indication for the removal of the nail.

In those cases in which the danger of a wandering out of the nail or a wandering into a joint exists this process must be counteracted by appropriate means. In most of the cases it will suffice to replace the nail by a thicker nail or to bend the nail head.

#### B. The marrow nailing of fresh gunshot fractures.

It is hazardous to apply the marrow nail method to the treatment of compound fractures and this is particularly true for fresh gunshot fractures because in these cases the conditions are much more unfavorable. In most of the cases the injured persons are physically and psychologically exhausted because of their participation in a battle, etc. Very frequently their state of nutrition is considerably reduced due to insufficient or irregular food supply, etc. Locally the conditions are much more serious than in compound fractures observed in peace time. The wounds are much more soiled, particularly with earth. The most fundamental difference, however, is the fact, that in these cases we have to deal with much more serious and extensive damages of the tissue because of the power of the bullets. The speed and power of modern bullets is so great that large areas of tissue distant from the track of the gunshot wound are seriously damaged. Extensive parts of the wound become necrotic a couple of hours or days later because their vessels are most seriously damaged by the concussion wave of the bullet. But also the tissue which did not become necrotic is most seriously damaged. The author has again and again made the observation in this war that even 2 or 3 years after the injury and even in those cases in which the wound was absolutely healed the least interference frequently resulted in infections despite the fact that greatest care had been given to all aseptic precaution-



ary measures. A tissue of that kind has for a very long period of time - if not forever - a decreased power of resistance against infection. Plastic surgery must take this into consideration (see chapter VI E and F).

On the other hand the use of the marrow nail under campaign conditions seems to be of great promise due to the fact that with the advantages of this method a great many complicated problems may be solved. At all times the problem of transportation of patients with gunshot fractures existed. During the last war with its extended frontiers this problem had a much greater significance, principally in consideration of the fact that we had a mobile warfare. The experiences gathered in this war proved absolutely clearly that the traction bandage is not practical. On the one hand the traction bandages are too large considering the means of transportation at hand, and on the other hand - and this is the important point - it is not possible to guarantee a minimal stable fixation of the fragments during the evacuation. Wounded soldiers treated with the traction bandage crowd the field hospitals and we must not forget that every one has to stay there for a couple of months. According to my experiences even the evacuation of soldiers with leg gunshot fractures to the field dressing station proved to be harmful and in all those cases flare-ups of temperature of the patients were observed. Consequently the changing of the dressing had to be made in bed which was scarcely possible in the field hospitals because of lack of time. In addition, a plaster cast does not provide an absolute fixation because it is not possible to eliminate the so-called millimeter-movements of the fragments (see chapter III). Consequently it is also not possible to counteract their influence upon the progress of the infection. Furthermore we must take into consideration that a cast hardly permits recognition of the much feared tube abscess of the thigh, first of all because in many cases it develops without any rise of temperature. Similar conditions prevail in anaerobic infections, gas-gangrene and malignant edema. In such a case the plaster cast must be opened or removed which, at least in most of the cases, cannot be made or at least only with difficulty during the evacuation. The plaster cast cannot prevent most serious dislocations. Even with large windows in the plaster cast the wound becomes seriously soiled by suppuration.

According to RUECKERT a pronounced shortening can be avoided with KLAPP's wire fixation and simultaneous plaster cast. In this way it is possible to have larger windows in the cast.

A good suspension position of the injured extremity can be achieved by using many wires the tension-bows of which are plastered into a framework in the shape of Braun's splints. Those wires run through the crest of the ilium (in its longitudinal direction), the trochanter, the femoral condyles, the tuberositas tibiae, the distal end of the tibia, calcaneus and metatarsal I. This arrangement allows a good accessibility of the entire leg. In accordance with KLAPP's principles on the rotary bed I have brought the entire body into this rest-



ing position in all cases of spinal gunshot injuries which were treated in field hospitals. For this purpose we used 12 mm thick iron bars, which in general are used for the construction of concrete dug-outs and made three circular rings with a diameter of 1 meter each. These rings were united by four pieces of bar iron made of the same metal. The pelvis and the legs were fastened to this frame work in the described way. The body was fastened by Kirschner wires running in the longitudinal direction through the clavicle. A limitation of the arms was avoided. All patients were well satisfied and quickly became accustomed to this apparatus. In this way the evacuation was very much facilitated.

All these suspension positions have the disadvantageous effect that the development of edema in the lower parts cannot be avoided as for instance with the rotary bed. The main disadvantage however is the fact that due to the conditions prevailing in field hospitals infections about the Kirschner wires frequently occur. In such a case those wires must be removed and consequently the entire apparatus cannot be used anymore. It is a matter of course that the so-called millimeter-movements cannot be prevented with this apparatus.

Due to the extremely large areas into which this war extended, particularly on the German side, most difficult and long lasting evacuation of wounded were necessary. Thus the surgeon as well as the nursing personnel had to be changed often. Under consideration of all these conditions it will be understandable that the results obtained in the treatment of gunshot fractures are very bad. Frequently shortenings of 10 and more centimeters were observed in cases of transverse thigh fractures. Moreover we frequently had to deal with angulations up to 90° and most serious stiffenings of the joints of all kinds, pseudarthroses, etc. after the patient had been brought to a hospital in the home territory.

These disadvantageous effects could be prevented in a large measure by marrow nailing. The extremity is readily accessible from all sides so that gas-gangrene as well as tube abscesses may be detected at an early date. Furthermore it is easy to observe the exterior of the extremity. For these reasons and due to the fact that the marrow nail should not be removed until an absolute consolidation of the fracture site is obtained, the frequent changing of the surgeon and of the nursing personnel in no way interrupts the fixation of the fracture. This fixation is absolute. Even under most difficult conditions of transport millimeter movements are quite impossible if the marrow nailing was made in the correct way. Furthermore an early movement of the joints usually is possible.

All this is very impressive. The only question is whether or not these enormous advantages can be obtained only by accepting the increased danger of infection due to the insertion of the nail into the marrow cavity. This question however can be answered only after we have gathered further experiences. (EDITOR'S NOTE: Dr. KUENTSCHER served in an Army Field Hospital on the Finnish Front for a number of months. Evacuation of the wounded was by rail to a seaport and by ship back to Germany where the wounded were again distributed by rail. It is of further interest to know that a review of the Marknagel procedure, prepared by Dr. KUENT-



SCHER on request, was published in English in the Finnish Annals of Surgery and Gynecology, 1948, Volume 37, Number 2).

### 1. HEIM's method.

HEIM was the first to nail fresh gunshot fractures. He made his operations with much care and used the following method:

(1) On principle all thigh gunshot fractures, even the ones suitable for the marrow nailing method, have in the first place to be treated operatively in order to obtain a fixation of the wound and of the fragments (wire extension).

(2) The patient may be nailed only when free from fever.

(3) The fracture must not be nailed from the wound.

(4) Before the nailing the patient must be given an intensive course of a prophylactic sulfonamide (Globucid).

He had at his disposal the most modern means of transportation and installations. He made five gunshot operations of the thigh under the above mentioned condition and all patients were in good general condition. He first excised the wounds and then a traction bandage was applied. After that he waited until all inflammatory symptoms had subsided and the patient was free from fever for a period of 3 - 4 days. Also the blood values had to be satisfactory and then he administered high doses of sulfonamide for a period of 4 days.

The nailing operation itself was made without touching the wound in much the same way as in simple fractures (chapter V). This means that he made a small stab incision which after the operation was closed by a suture. Furthermore the entire operation was made under X-ray control (fluoroscope). HEIM gained the impression that in this way the reduction of thigh gunshot fractures was much easier on an average than the reduction of simple fractures. This may be due to the fact that in simple fractures the intact muscles considerably resist the reduction process. Also in this connection the high speed of the bullet which damaged the muscle is of great importance. In all cases manual traction at the extension apparatus (with the counter traction fastened at the perineum) sufficed to counteract the shortening. It proved to be particularly suitable to maneuver the proximal fragment by means of the partly inserted nail during the reduction (see chapter V). In this way the distal fragment is not brought into the same direction as the proximal fragment. This is contrary to the usual procedure. Both fragments are set together and in this way the movements at the fracture site are less, which is of utmost importance regarding the stimulation of the infection. HEIM asserts that patients treated in this way were transportable a couple of



days later and the results obtained in this connection were much better than those with transportation splints, etc. Patients who had suffered simple transverse fractures were able to get up three weeks after the nailing. Also comminuted fractures were nailed but the patients had to be confined to bed for a much longer period of time because of the danger of shortening. In this case the nail acts as a guide-splint around which callus and bone splinters as well form a new bone tube.

He has treated only five cases so a final evaluation of his method cannot be made. Fundamental objections against this method do not exist and it is the author's opinion that even in a large number of cases with the same favorable conditions similar good results could have been obtained. HEIM himself points to these facts and he is of the opinion that with regard to the conditions prevailing on the Eastern Front his method could not be used there.

The results obtained in his five cases are absolutely good ones. In all cases after the insertion of the nail the reaction of the blood was amazingly slight and lasted only a couple of days. The blood picture was normal. A reactivation of the infection of the soft part wound was in no case observed. The wounds rather showed a tendency to heal more quickly. An infection of the bone marrow, of the lymphatic vessels and of the lymph gland as well was not observed. A formation of sequestra was in no case observed, neither clinically nor roentgenologically. A demineralization of the bone or a spotty atrophy was so far not yet observed in the X-ray. After a limitation of the joints and of the gait no longer existed all patients were sent to the home territory for a period of 6-8 weeks. After their return the nails were extracted and 1-2 weeks later the soldiers were sent again to the front-line. In three out of five cases of nailed gunshot fractures of the thigh a release from the hospital was possible relatively early.

In no case did a limitation of the joints exist. In one case of a comminuted gunshot fracture, however, a shortening of 2 cm. was observed. In all other cases a shortening did not exist. In the following I am giving you two patients' records by HEIM:

Case # 1.

Mech.Corp. F.W.: Thigh gunshot fracture caused by a 2 centimeter bullet (Spitfire). The patient was brought to the hospital 2 hours later. Moderate wound and transport shock. Immediately after his hospitalization the patient was given a tetanus antitoxin serum, 20 cc. of Globucid intravenously, Periston and Tutofusin. After a lapse of half an hour wound treatment, wire extension and Globucid for a period of 4 days. On the 8th day, the patient was free from fever. Slight wound secretion developed and then the patient was given a second course of Globucid. On the 5th day a marrow nail operation was made and the wire extension was removed. For a period of 2 days there was an increase of the temperature up to 37.5°C. After that, the patient was permanently free from fever. The wound healed



quickly. On the 21st day after the nailing an impediment of the joints did not exist. The patient was able to get up on the 24th day after the nailing (without using a cane) and the wound of the soft parts is healed and scarred. Twenty-eight days later he went on leave for a period of 8 weeks. After his return the nail was extracted, and 21 days later he was returned to his unit as fit for service. No further after-treatment.

Case # 5.

Boatswain's mate A.K.: Thigh gunshot fractures in both legs on the right side the transverse fracture is smooth, on the left side we have to deal with a comminuted fracture, and gunshot fracture in the arm above the elbow on the right side and a lower jaw gunshot fracture due to secondary bullets aboard ship during a sea battle. The patient was brought to the hospital 7½ hours after the injury and we observed a serious wound and transport shock and a serious loss of blood. The pulse was barely perceptible. Immediate blood transfusion of 550 cc., 1500 cc of Tutofusin and Veritol and Sympatol, 500 cc. of Periston, 20 cc. of Globucid intravenously and tetanus antitoxin serum. The patient recovered ¾ hour later and the wound treatment started immediately (S.E.E. strong intramuscularly and local anaesthesia) and wire extension on both sides. A Globucid course was started. The wound infection was minimal. The patient had temperatures of 37-38°C for a period of 18 days and his general condition improved only slowly. On the 20th day he was given a second course of Globucid and on the 25th day both thighs were nailed at one operation (which lasted 43 minutes). The wire extension was removed. The general reaction was slight. On the 1st and 2nd day post-operatively the temperatures were normal. Between the 3rd and 7th day after the nailing the temperatures were between the limits of 37.1° and 38.2°C. After that the patient was free from fever. Fourteen days later the patient started with passive movements of the joints during his confinement to bed. The wounds came to a good healing. From now on the patient recovered quickly. Due to the compound fracture on the left side the patient could get up only 8 weeks after the nailing. In the beginning he had to use two canes when walking, but after a lapse of five more weeks canes were not required anymore. An impediment of the hip joint, knee joint and of the ankle joint did not exist. The X-ray revealed that not the slightest demineralization had occurred. The nail in the transverse fracture was removed but the other nail (comminuted fracture) was kept in place. After that the patient was sent on leave (he travelled without escort). After his return his gait was unhampered and he was able to walk upstairs and downstairs. After that the second nail was removed. He was able to make a deep knee-bend without any difficulty. Spreading of the legs was not hampered. On the left side there existed a shortening of 2 cm. and a slight limp was observed which was counter-acted



by a thicker shoe-sole. No after-treatment. The gunshot fracture of the arm above the elbow and the lower jaw gunshot fracture as well came to a good healing.

## 2. BOEHLER's method.

BOEHLER treats fresh gunshot fractures after the same principles applied to compound fractures in peacetime in order to give gunshot wounds the same great advantages of a primary healing of the wound. Consequently the operation must take place within the 6-8 hour limit which means that the marrow nailing must be made, so to speak, in the front line at the main dressing station. BOHLER himself made two marrow nailings of that kind in Russia with most exact wound excision, insertion of the nail from the site of the wound and precise suture. Both cases came to an ideal healing with no impediment of the joints. In both cases, however, an infection occurred. Consequently the wounds had to be opened and the suppuration lasted for a very long time.

The author is of the opinion that with regard to the conditions prevailing at the Eastern front this method seems not to be suitable. At the main dressing station to which the author was assigned most cases of gunshot fractures did not arrive within the 6-8 hour limit which was due to the bad transport conditions. Moreover, good aseptic conditions which are required for the excision and the use of early suture cannot be achieved at a main dressing station in Russia, considering the conditions under which we had to work and the billets at our disposal. Furthermore we had to take into consideration that we did not have available well-trained personnel which would have made it possible to observe the sutured fractures constantly and to open the wound in due time in case the symptoms of a beginning infection appeared. Finally the author is of the opinion that from the technical point of view the entire soiled tissue in gunshot wounds cannot be removed because of the many pockets in those wounds. As already mentioned above, large areas of tissue are damaged so much by the wave of concussion which is due to the speed and power of modern bullets that these areas become necrotic even after a lapse of some time. Symptoms of this kind, however, can in most cases not be observed in the beginning. In general surgeons attached to main dressing stations do not dispose of the necessary time to make a careful marrow nailing. Most of their time is urgently required for the elimination of life-endangering conditions, etc. Therefore the author has developed a method of his own.

## 3. Method of KUENTSCHER.

This method is based on the experiences made during the Russian campaign. Due to the difficult conditions we must set aside FRIEDRICH's wound excision and suture. The wound must be treated as if it were infected. Consequently it must



be opened widely and all pockets, etc. must be split if possible. It is a matter of course that gross soil and necrotic tissue must be removed. We must, however, desist from excising small soiled particles. The wound must not be sutured. On the contrary, it must be kept open by tampons, drainage and even by clips.

In this way we voluntarily renounce the great advantages of the primary healing of the wound with their favorable influence on the soft parts and the bone. We achieve, however, a considerable decrease of the hazard of infection. We must keep in mind that the above mentioned advantages which are due to the excision of the wound can be obtained only in few cases considering the fact that despite all precautionary measures the quota of infection is enormously high.

The question is whether or not such a secondary healing is compatible with the marrow nailing. Let me give you the answer right away: The marrow nailing can be made during the process of secondary healing. It was proved by experience that even in cases of most serious suppurations the wounds above the nail close and the nail heals in in much the same way as in simple fractures with an absolutely aseptic course. This finding is contrary to all surgical experiences made known so far which say that in all cases in which suppuration exists around a foreign body a healing cannot be obtained as long as that foreign body is kept in place. This should particularly be true for such a large foreign body, as the marrow nail. It seems to me that in this connection the non-irritating effect of the nail and its smooth surface are of decisive importance. The healing in of the nail is due only to this circumstance and consequently the marrow nail can be used for the treatment of gunshot fractures during secondary healing. In all cases observed a secondary healing was achieved. In those cases in which pus fistulae existed, the nail could not be blamed for their origin. In all those cases it was proved that those fistulae were due to sequestra or abscesses of the soft parts. After their elimination the wounds came to a healing. This method grants the following advantages:

1. FRIEDRICH's 6-8 hour limit need not necessarily be observed.

2. In this way the marrow nail method can be applied to a larger number of cases because also those patients may be nailed who are brought to the hospital later than after 6-8 hours.

3. The nailing operation can be made later, i.e. at a time more suitable to the surgeon so that urgent operations of the abdomen, etc. can be made first.

4. In this way marrow nailing operations must not be made ~~any more~~ at the main dressing station or in the field hospital but in the rear hospitals, after most thorough examination.



According to experiences made at Kemi (Finland) it was proved that it is disadvantageous to nail fresh gunshot fractures within the first hours after the injury. This is due to the fact that the already existing wound shock is increased by the shock caused by the operation. In two cases most serious conditions of collapse were observed despite the fact that all possible precautionary means had been used. These conditions subsided only 2-3 days later. In all other cases of marrow nailings which were made a couple of days after the injury symptoms of shock were not observed.

5. A very thorough excision of all wound pockets (which in most of the cases cannot be obtained anyhow) is not required. In this way much time is saved. It will suffice to open the wound widely and to remove the worst soiled particles and torn out tissue.

After we had found out that it is unsuitable to nail during the very first hours after the accident all the other cases were treated in the following way:

A wound revision was made at the main dressing station but sutures were not applied. After the application of a temporary cast or splint bandage the patient was brought to the field hospital and later to the base hospital. Here the patient got a rest and during that time we selected all cases suitable for the marrow nailing operation. Stabsarzt (Captain, MC) Dr. FISCHER who was head of that station helped me very efficiently in this connection.

This selection was made after a thorough examination of the X-rays and in this way it was determined which fractures were mechanically suitable and which ones unsuitable for the nailing method regarding the location of the fracture. All cases of fractures of the joints or near the joints were exempt and had to stay in this station. The estimates we made were rather rough. So we nailed 5 supra-condylar fractures of the arm above the elbow in which the nail penetrated the distal fragment only  $1\frac{1}{2}$  or 2 cm. At the same time we nailed also those cases in which the patient was in a bad condition of health or even in fever. In general it seems to be advisable to wait until the sometimes very active symptoms of infection have subsided with the patient in the transport cast. It might even be necessary to incise abscesses, etc. until finally the infection is brought under control. Most of the cases were treated in that way. In no case, however, did we desist from nailing because of fever or the bad condition of health of the patient. All operations were made during the period between the first and the 21st day after the wounding even with the presence of a mild infection.

All fractures treated within this period were considered as "fresh gunshot fractures". It is difficult to define which gunshot fractures are "old" and which ones "fresh". Anyhow, in this report the limit is set at the 21st day, in a somewhat arbitrary manner.

The marrow nail operations were made at the hospital at Kemi (Northern Finland) in which all modern apparatuses



for these operations were available. Kemi was most favorably situated for this purpose. There was no other place at the numerous fronts where such an exact control could be made during the evacuation of the wounded because there existed only one route. Consequently every wounded soldier was included in our statistics. As to brain injured soldiers special air transport facilities were available at all parts of the very extended frontiers and so no difficulties were encountered in obtaining the necessary transportation also for cases of gunshot fractures. Due to this fact all cases of this kind could be nailed within a couple of hours after the wounding. In this way we were in a position to find out the most suitable time for the nailing.

#### Tools for the nailing of gunshot fractures.

All gunshot fractures were nailed in the septic operation room, which was located in the same building. Operations of this kind may, however, also be made in a field hospital because a regular operation room suffices for this purpose. An X-ray apparatus, however, must be available. In some cases a "Siemenskugel" (a portable apparatus made by Siemens) sufficed. For the nailing of the forearm and the arm above the elbow special apparatus is not required. A simple wooden table acting as an extension of the operation table suffices. Leg fractures were nailed with the help of the well-known BOEHLER's leg-extension apparatus which was used without any modifications. Thigh fractures were nailed on the extension table with the patient in supine position. In most of the cases a relatively small traction force was required which confirms HEIM's experiences. This posture of the patient can be achieved also by using a field operation table and an extension apparatus. The patient is lying on the sound side with the hip flexed so that the lateral aspect of the injured thigh is above. A padded belt is led between the legs which is attached to the table at about the height of the shoulder blades. Canvas anklets on which the extension acts are attached on both feet. A scale for the measuring of the force in action was not used. It was determined according to the distance of the fragments one from the other. This was easily achieved, because we had to deal only with compound fractures. It is very important however, that a sufficient quantity of all sorts of nails and a complete armamentarium are available and, above all, the extraction apparatus. The transport casts were removed with the patient under evipan and later in ether anesthesia. After that the patient was brought into the above described position on the operation table. The entire area of the fracture site was disinfected by means of iodine tincture which was then covered by means of cloths. In most cases of thigh gunshot fractures a wound on the lateral aspect of the thigh was observed. In these cases an incision of 10-15 cm. was made. In those cases in which a wound did not exist, an incision was made at the level of the fracture site, in most of the cases somewhat in the dorsal direction in order to facilitate the draining off of the wound secretion when the leg was rotated somewhat laterally. In the arm above the elbow the incision was made - if possible,



on the extensor side. The wound at the nail insertion side was likewise made as long as possible and amounted to 8 cm. in the thigh, and 3-5 cm. in the leg, 3-4 cm. in the arm above the elbow and 2 cm. in the forearm. Special attention must be paid to the wounds at the insertion site, because those wounds are the spots where the secretion drains off. In this way the gunshot fracture is additionally drained from within, for the marrow nail acts as long drain tube. It is located at a somewhat peculiar spot: in the marrow cavity. It was proved by experience that this location is of no harmful effect.

After that the reduction must be made which can be obtained with slight traction forces as already mentioned above. The lateral shifting of the fragments is made by means of the fingers which must be introduced into the gunshot tract, i.e. by direct palpation. If possible the bones should not be pulled out of the wounds in order to prevent a damaging effect upon the periosteum which in this connection is much more important than in the case of an osteotomy. The periosteum must not be separated from the bone and the soft parts. All bone particles separated from the periosteum will in all cases form sequestra as soon as a suppuration occurs. This, however, means that one of the great advantages of the nailing method no longer exists and an operation of this kind would be about equal to a bone suture of the gunshot fracture. Consequently only a few retractors should be inserted into the wound. Also the fingers should be inserted as little as possible and in the first place they serve to touch the ends of fragments. With some skill, it is easy to get along in this way for we still have the two X-rays arranged in two different planes. It is not difficult to find the two openings of the marrow cavities of the distal and proximal fragments. In case of a thigh fracture the guide rod is inserted in the usual way (see chapter V), from the trochanter until the finger touches the nail tip in the proximal marrow cavity. After that the finger leads the rod into the marrow cavity of the distal fragment. In general a slight pressure suffices to counteract the lateral displacement. If this process is not successful the assistant must grasp the entire thigh according to the directions given by the surgeon and reduce the fragments. In complicated cases the reduction is considerably facilitated by driving the nail somewhat into the proximal fragment. The nail projecting from the insertion site serves in this case to maneuver the proximal fragment (see chapter V). As soon as the surgeon observes that the tip of the guide rod has reached the opening of the marrow cavity of the distal fragment the guide rod must immediately be inserted more deeply, about 5-8 cm. After that the nail is inserted as usual by slipping it over the guide rod. The advance of the nail through the fracture cleft and into the distal fragment may well be controlled by means of the finger. Consequently an X-ray apparatus is not urgently required for the marrow nailing itself. This means that in this way the operation is very much facilitated and shorter. X-rays are required however, for the pictures to be taken before and after the operation. In cases of long oblique fractures it sometimes will be difficult to determine with the finger whether or not the nail has entered the marrow cavity of the distal



fragment. In cases of this kind the author has always fluoroscoped the fracture site after the operation by means of the "Skiascope". In all the other cases X-rays were taken later after the patient had been brought to bed. Special consideration must be given to subtrochanteric fractures in which the exact location of the nail must be determined precisely.

The method of introducing the guide rod into the proximal fragment from the fracture site may also be applied to gunshot fractures. The tip of the guide rod pierced through the skin serves to indicate the insertion site of the nail (see chapter VI). In such a case, however, the proximal fragment must be brought a little bit more to the surface of the wound. In subtrochanteric fractures greatest care must be given that the guide rod does not leave the neck of the femur too far medially (see chapter VI). We must take into consideration that in such a case the guide rod is not led through a long piece of marrow tube. Consequently after the insertion of the end of the guide rod the distal fragment must be deeply pressed into the wound as described in detail in chapter V, so that the guide rod is angulated. Only after that may the guide rod be driven in further.

First of all, however, repeated movements of the guide rod forwards and backwards must be avoided and in no case may bone splinters be removed. Even in the case in which those splinters are getting necrotic and become sequestra we must not forget their strong stimulating effect upon the formation of new bone. The stimulating substances mentioned in chapter III are probably freed this way and cause the periosteum and maybe also the connective tissue to form new bone.

The wounds were treated only by sprinkling "Marfanil" into them. It is a sulphonamide invented by DOMAGK.

The wounds were loosely filled with gauze tampons which were removed 48 hours later. Sutures were not used.

When treating gunshot fractures in this way their marrow nailing is a relatively conservative operation which in general lasts only a short time. The reason for this is that the difficulties encountered with the reduction are only slight. The nailing operation of a thigh gunshot fracture lasts only 15-40 minutes. In some cases the reduction may be more complicated and consequently the operation may last up to an hour.

The marrow nailing of the leg, the forearm and the arm above the elbow is made from the usual insertion sites (see chapter V). In those cases a guide rod was never used but the nail was in all cases inserted without it. Also in these cases the reduction process as well as the exit of the nail were almost always controlled by direct palpation with the finger.

In our first nailings the thigh was held by means of a Braun's splint which later on proved to be unsuitable. In



this case the thigh runs obliquely from below to above and thus the pus runs from the fracture site toward the hip joint causing in this way a long tube abscess. The most suitable arrangement of the patient is flat if possible with his head about 30-50 cm. higher. In most of our cases we used only sand-bags. In some cases, however, we used the Volkmann splint, which has the disadvantage that the leg is rotated too much inward. Only one plaster cast was applied and this because of the existence of a knee empyema.

The fixation of the fracture site by the nail seemed in all cases to be sufficient. In some cases of serious infection, however, the application of an additional plaster cast seems to be advisable in order to immobilize the adjacent joint as well.

In two cases of thigh fractures additional extension bandages were applied using a Kirschner wire which was led through the tuberositas tibiae. In both cases we had to deal with fractures which were located so close to the knee joint that the nail alone did not suffice to grant sufficient hold. In a number of gunshot fractures in the forearm and in the arm above the elbow in which serious inflammatory swellings were observed, fixation bandages made of Kramer splints were used for some time. In one case in which a simultaneous primary infection of the shoulder joint existed, an abduction splint was attached. Most of the cases, however were treated without any additional splints.

As soon as the fever had subsided the patient had to start subjecting the limb to exercise movements. In arm fractures special consideration was given to the abduction movement in the shoulder. After the wounds had become smaller and if they looked good the patient had to get up. In the cases of thigh gunshot fractures we did not wait until the wounds were entirely healed, in order to prevent any stiffening of the joints. It is a matter of course that we were conscious of the fact that the healing of the wound would in such a case require somewhat longer.

Due to the insertion of a marrow nail into a gunshot fracture the fracture itself is practically eliminated and we have to deal only with a wound, which must be treated in accordance with the respective principles of war surgery. So a patient suffering an injury of the soft parts of the thigh cannot be kept in bed until the wound is completely healed. In 39 out of 54 cases of thigh gunshot fractures the patients got up 3-4 weeks after the wounding. In 30 out of 37 cases of upper arm fractures the patients got up 14 days after the wounding and in 16 out of 18 forearm fractures the patients also got up 14 days after the wounding. In those cases however, in which, due to an extensive infection of the soft parts the patient was not free from fever, the confinement to bed lasted much longer, in some cases even months.

The same conditions prevail in connection with the transportability of the patient. As soon as the wounded



soldiers are free from fever they are also transportable. In order to obtain precise observations and for statistical reasons the patients were kept in the hospital until a satisfactory healing was achieved. In this way we were in a position to study the further course of the wounding. The author has also extracted all of the nails himself and after that the patients were further observed for a period of 1-2 weeks. Due to the sudden collapse of the front all cases of marrow nailings had to be sent hastily to Germany on September 6, 1944. There were 56 patients, 26 of which were 5 week old leg fractures. Despite the fact that the patients had to be evacuated over more than 2000 kilometers, the author was in a position to prove that all of the patients arrived in fairly good condition and none of them had died. It is a matter of course that all of them were rather exhausted. Furthermore we must take into consideration that plaster casts could not be applied because of the sudden and unexpected departure. All cases were thoroughly studied in the homeland by OEHLECKER and during the Surgical Congress at Hamburg in October 1947 he gave us a survey about the results obtained. All fractures were healed in good position. This report was confirmed by EHLEFELD in a personal letter to this author.

So the decisive question in connection with the nailing of fresh gunshot fractures is whether or not the marrow nail operation may be blamed for a more serious and more frequent infection.

In 74 out of 116 cases of fresh gunshot fractures (64%) an infection was observed. These figures must be subdivided as follows:

Table of the healing of wounds in fresh gunshot fractures.

	healing of the wound per gran- ulationem	healing of the wound per se- cundam	total
Thigh	16	36	52
Leg	2	5	7
Arm above the elbow	21	16	37
Elbow	-	1	1
Radius	-	1	1
Radius and ulna	-	11	11
(Forearm total)	(3)	(15)	(18)
Clavicle	-	1	1
Total	42	74	116
Percentage:	36%	64%	100%



According to some statistics published by BOEHLER during the first World War 513 out of 601 cases of gunshot fractures (85%) were infected. Other statistics show similar figures. When referring to those publications I do not do so as a means of proving that the results obtained in this connection by the marrow nail methods are better because of the more favorable conditions of immobilization. In the first place the total number of cases treated is much smaller and so the statistical mistakes are also greater. On the other hand, however, our more favorable results may be due to the sulfonamides which were given in nearly all cases.

In 6 out of 116 cases (or 5.2%) a fatal termination occurred (5 gunshot fractures of the thigh and 1 gunshot fracture of the arm above the elbow). This means that 9.6% of 52 cases of thigh gunshot fractures came to a fatal termination. But also in this case the statistics are not correct. Nevertheless I would like to refer to some statistics from the first World War:

Table of thigh gunshot fractures (according to BOEHLER)

	Total	Mortality	Amputations	Survived and not amputated
American Sanitary Report	3,296	24.4%	36.7%	38.9%
French Sanitary Report	37,746	13.7%	28.9%	57.4%
Communication Zone Hospital, single German statistics	1,675	23.3%	12.5%	64.2%
BOEHLER (World War 1914/18)	111	10.8%	2.7%	86.5%
ARGUELLES (Spanish Civil War)	316	8.9%	7.2%	83.9%
JIMENO VIDAL (Spanish Civil War)	600	3.6%	1.6%	94.8%

These figures of mortality were considerably higher in front line hospitals and amounted to 42% according to FRANZ. It is a matter of course that the hospitals situated more distant from the front line and which, so to say, get their wounded out of second or third hand achieve much better results. The fatal terminations occur before the most seriously injured persons reach those hospitals and consequently those cases do not appear in the statistics of the base hospitals.

Two of the six fatal terminations had been amputated. One of the other amputated patients survived so that the total number of those patients who had survived and who had not been amputated amounted to 46 or 88.5%. In all the o-



ther fractures amputations were not done. The clinical records of the fatal terminations read as follows:

1. A. D. suffered a gunshot fracture of the thigh and a wound 5 x 5 cm. on the lateral aspect of the thigh which suppurated. The fracture was a comminuted fracture at the limit of the lower third. The nailing operation was made on the 10th day after the wounding. After a lapse of 4 weeks the patient was free from fever, but he could not get up because of the comminuted fracture. Seven weeks after the wounding the patient came to a sudden fatal termination out of good general conditions. The autopsy revealed that he had suffered a massive lung embolism caused by a thrombosis of the iliac vein.

The four other cases were due to infection:

2. I.B. was wounded on August 16, 1943 by a shell splinter which caused a subtrochanteric comminuted fracture. Four days after the wounding an extensive gas phlegmon at the fracture site had to be opened. The fever amounted to 39°C and the patient suffered severe pains. A marrow nail operation was made on the 14th day after the wounding. After that the patient was free from pain. The fever decreased slowly by lysis within 5 days. Ten days later the temperature increased again and later on a large sized tube abscess of the thigh was observed and at the same time a knee joint empyema. Consequently the limb was amputated. Eight days later the patient died. The autopsy revealed that a large sized psoas abscess had existed which had penetrated into the pleural cavity.

3. J.J. had suffered a transverse fracture in the middle of the thigh which was due to a shell splinter. Seven days after the wounding the patient was nailed despite the fact that he was not entirely free from fever. After that a long tube abscess developed which required several incisions. Nevertheless the temperature rose again and the case came to a fatal termination 7 weeks after the wounding. The autopsy revealed the presence of a tube abscess in the thigh which, however, was open. Further centers of infection which might have caused fever were not observed, but a "septic spleen" and damage of the myocardium were found.

4. O.Th. had suffered a comminuted fracture of the thigh caused by a shell splinter. There existed 2 wounds 5 cm. wide on the lateral aspect and two wounds 2 cm. wide on the medial aspect of the thigh, and several small wounds all over the leg. The marrow nail operation was made 14 days after the wounding. The wound was covered with pus, the patient however, was free from fever. During the first week the condition of the patient was normal. After that time he suffered a bronchopneumonia on both sides. Eight



days later the temperature decreased by lysis but 4 days after that the temperature rose again. A small tube abscess had to be opened and 2 days later a pleural empyema on the left side had to be aspirated. One liter of pus drained off in which pneumococci were observed. Fatal termination occurred 5 weeks after the wounding. The autopsy revealed that he had suffered a pleural empyema on the left side and had an incised tube abscess of the right thigh. There was a knee-joint empyema which was due to a damage of the knee-joint capsule the size of a pea caused by a shell splinter. In this case the fatal termination was probably due to the marrow nail operation. The narcosis must probably be blamed for the pneumonia but it was necessary for the operation. The knee joint empyema could not be observed clinically because of its mild state. It was not due to the marrow nailing because there was a small injury in the knee.

5. M.L. had suffered a gunshot fracture on the right thigh caused by a shell splinter. At the lateral aspect of the thigh a torn out wound the size of the palm of a hand was observed. It was a comminuted fracture 6 cm. long, a hands breadth above the condyles. In the front thorax wall on the right side two wounds, each 2 cm. wide, were observed. The X-ray revealed that two splinters the size of a pea were located in the dome of the liver and in the right lower quadrant. His general condition was not so good. The temperature was 38.2°C. His condition did not change after the nailing. Later on his condition slowly grew worse and the temperature increased. After a lapse of 4 weeks a tube abscess in the thigh was incised. After that the fever was only slight. The amputation was made after 6 weeks and 8 weeks after the wounding the patient grew increasingly weaker and died. The autopsy revealed a damage of the myocardium and a septic spleen. No further abscesses.

6. L.G. had suffered an extensive comminuted fracture in the right arm above the elbow with a torn out wound the size of the palm of a hand which was located on the lateral aspect of the arm. Furthermore he had suffered an extensive comminuted fracture of the metatarsal V of the left hand and an extensive serious phlegmonous inflammation of the left dorsum manus and an extensive phlegmon of the right leg with foul smelling secretion. The phlegmons were widely incised and after the general condition had become better a marrow nail operation was made, 10 days after the wounding. After that the fever decreased for a couple of days but shortly later the temperatures were once again high. The left hand and the right leg had to be incised several times. The nailed arm was normal. The fever stayed high and the temperature curve showed septic symptoms. After that somnolence and a slight icterus were observed. The patient died 14 days after the operation. The autopsy revealed a general sepsis.



In the nailed arm neither phlegmons nor abscesses were observed. Only the gunshot wound showed a pus-like layer. The shoulder and elbow joints were flexible. The nail had forged a stable union with the fragments and the phlegmons in the left hand and in the right leg were wide open. The origin of the sepsis could not be ascertained. According to the clinical observations the phlegmons probably originated in the leg.

The third amputation patient was K.S. who had suffered a gunshot fracture in the thigh located a hands breadth distant above the knee joint. It was due to the effect of a shell splinter which had caused an extensive destruction of the bone. The patient was seriously anemic and exhausted. On the lateral aspect we observed a wound 5x8 cm. large and on the medial side another wound 4x4 cm. existed. The patient suffered high fever. The marrow nail operation was made the second day after the wounding, but the fever did not decrease. Suddenly the eighth day after the wounding an erosion hemorrhage from the A.femoralis was observed which was exposed deeply in the suppurating wound. Immediately the thigh was amputated at the fracture site. Due to the extensive damage of the vessels a suture could not be applied. A blood transfusion was given and the nail was kept in place. The temperature decreased to normal only two weeks after the amputation. Healing.

All fractures treated this way became stable. In no case was a pseudarthrosis observed.

In leg and thigh fractures special care was taken to avoid shortening and in the majority of the cases we were successful. The shortenings which occurred were not worth mentioning. We must, however, keep in mind that in simple transverse fractures considerable shortenings cannot occur.

As an example I would like to refer to the case of the wounded H. B. We had to deal with a torn out wound in the size of 2 cm. which was located on the lateral aspect of the thigh. The X-ray revealed that three shell splinters and a jagged transverse fracture existed a hands breadth below the trochanter minor. The patient did not suffer from fever and the nailing was made on the 7th day after the wounding. The shell splinters were not removed. The union obtained was absolutely stable and the fragments were in most ideal position (see illustration 207).

The healing process was normal and the patient was able to get up 8 days after the nailing and to subject the limb to weight bearing. Normal flexibility of the joints.

The wounded P.K. had suffered a transverse fracture in the middle of the thigh shaft which was due to mine splinters. Three wounds, each 2 cm. wide, were observed. The patient was free from fever. The marrow nailing was made on the second day after the wounding and an ideal strong union was obtained (see illustration 208).

The healing process was normal and the patient did not suffer from fever. He got up on the 20th day after the wound-



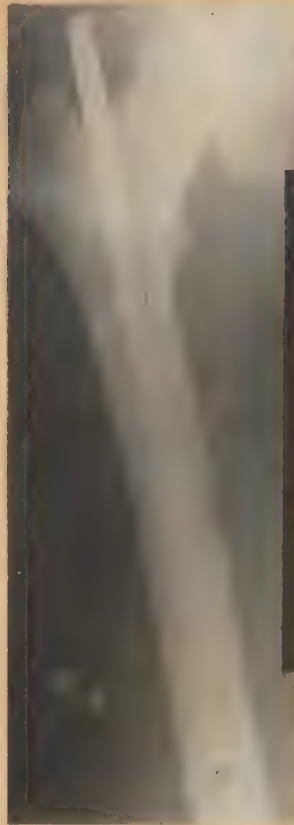
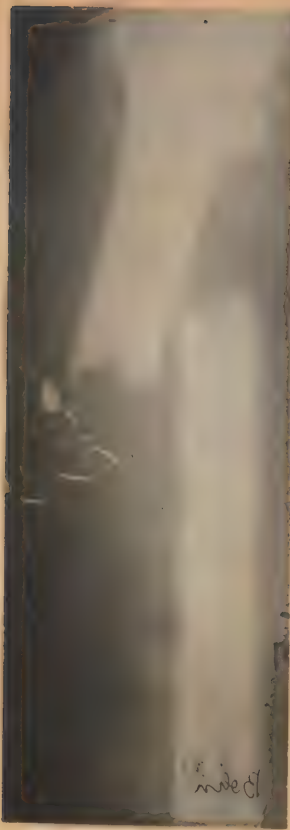
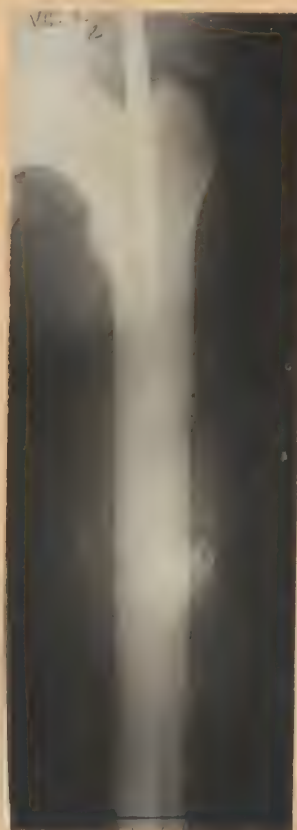


Illustration 207.

Gunshot fracture of the right thigh due to a shell splinter (patient H.B.) Ideal position of the fragments after the nailing.



a

b

Illustration 208.

- a) oblique fracture in the middle of the thigh due to mine splinters (patient P.K.)  
b) Ideal position after the nailing made on the 2nd day.





c

d

Illustration 208.

c) Same fracture 24 weeks later

d) Extraction of the nail 24 weeks later.

ing and the wounds were closed after a lapse of four weeks. The nail was removed 24 weeks later and the fracture was clinically healed. No muscle atrophy or impairment of the joints existed.

In these two cases of gunshot fracture extensive destructions of the bones did not exist. In general, however, areas of more or less marked destruction of the bone are observed. As soon as the marrow nail does not forge an absolutely stable union in the upper or lower part of the marrow cavity a shortening due to the muscle traction forces will occur which equals the extent of the zone of destruction. This means that in such a case the shortening comes to an end as soon as the intact proximal and intact distal part of the marrow tube bone stand one upon the other. The shorter the zone of destruction, the less marked will be the shortening. This must, however be avoided in the lower extremities. For this purpose we may apply either a traction bandage with all its disadvantageous effects or the author's "Spreizfluegel" (spreading wings). These "Spreizfluegel" are made of stainless steel and are inserted into the slit of the marrow nail. They are wing shaped and at the spot where they are inserted into the nail slot they are bent. We must always insert a set of two which are held together either by means of a screw, or which is better, by means of a loop led around them. In this way the two spreading wings cannot slip out of the slit of the nail. The spread wings must



correspond to the extent of the zone of destruction. If for example the destruction zone in the thigh amounts to 5 cm. we must also use 5 cm. long spread wings. Therefore we must always dispose of a sufficient quantity of such "Spreizfluegel" (see illustration 209).

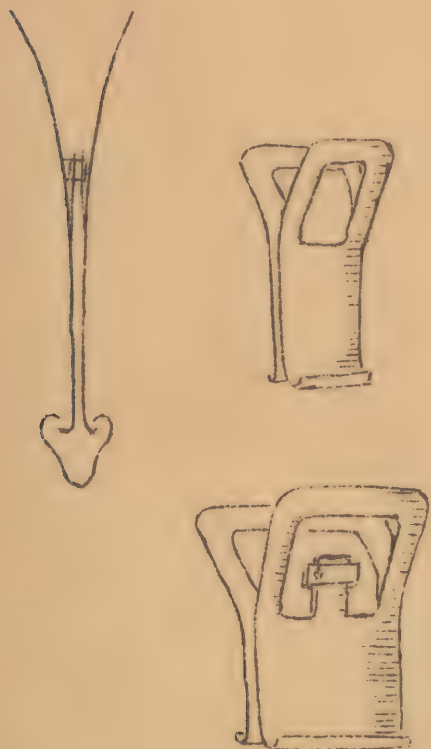


Illustration 209.

"Spreizfluegel" according to the author. Different lengths for the insertion into the nail slit in cases of comminuted and defect gunshot fractures.

These wings are applied in the following way: Before the operation the correct length of the wings is determined by means of the X-ray. For purposes of comparison the sound bone must be X-rayed. During the nail insertion process we must take care that the slit is always pointing to the operation wound. After that the leg must be pulled so much that a lengthening is obtained which corresponds to the size of the respective wing. After that the wings may be inserted one after the other into the slit of the nail which is now visible. They are then united either by a screw or by a metal loop.

These wings serve likewise to spread the wound (instead of a rubber drain) and keep the wound open for the draining off of the pus. In general the callus quickly fills up the defect because so many bone splinters are located around the nail. As soon as the callus is strong enough to prevent a shorten-

ing the spread wings must be removed from the nail slit. The nail itself is extracted many weeks later.

The following two examples are a demonstration of how to use spread wings:

The 23 year old soldier E.K. had suffered a complete destruction of the right thigh bone which amounted to  $2\frac{1}{2}$  cm. and which was due to the effect of a shell splinter. In front and on the lateral aspect of the thigh extensive torn out wounds were observed. The patient had lost much blood and slight shock existed. Infusions and blood transfusions were given and the torn out wound areas were excised and dirty parts cleaned under narcosis. A thorough excision of the wound was not possible because the wounds extended to the interior of the pelvis. After the sprinkling of the wound with Marfanil a splint was applied. On the 5th day a typical marrow nail operation was made. A  $2\frac{1}{2}$  cm. long Spreizfluegel was inserted. The course of the healing was



complicated because of high and severe fever which subsided only after a period of four weeks. The suppuration was less intense. Eight weeks later the spread wings were removed and the patient was able to get up. The marrow nail was extracted after 14 weeks and during that operation several sequestra the size of a bean were removed. After a lapse of 16 weeks there existed only two small fistulae on the lateral aspect of the thigh. The impediment of the hip was decreased considerably, the knee joint however was freely movable (see illustration 210).



a



b



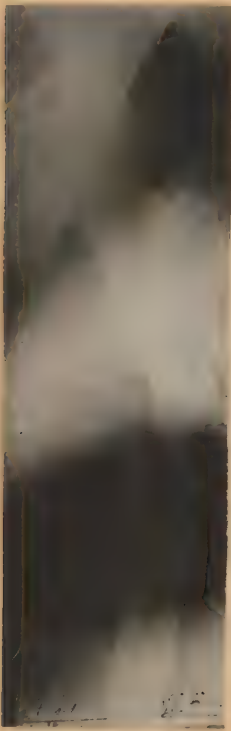
c

Illustration 210.

- a) comminuted gunshot fracture of the right thigh in the 23 year old soldier E.K. which was due to the effect of shell splinters.
- b) After insertion of the marrow nail and application of a  $2\frac{1}{2}$  cm. long spread wing (into the nail slit).
- c) Twenty-six weeks p.o. The nail has been removed.



If the defects are very extensive the spread wings must be correspondingly long. The insertion of the spread wing does not show any harmful effects upon the nerves or vessels because as mentioned above the operative wounds are always made on the lateral aspect of the thigh. Despite the usage of such enormous quantities of metal a marked disturbance of the formation of callus can certainly not be proved. Cases of that kind make it clear that the opinions expressed in a great many publications as to the harmful effect of the metal during the healing process of fractures should be revised at least in so far as stainless steel is concerned. The damages observed are in most of the cases due to mechanical conditions (see illustration 211).



a



b

c



d

Illustration 211.

- a) Extensive comminuted fracture due to shell splinters in the 26 year old soldier F.G.
- b) after the marrow nail operation and the insertion of an 8 cm. long spread wing.
- c) despite this large quantity of metal abundant formation of callus.
- d) after the extraction of the nail 10 weeks later.



Such spread wings may not be used in the upper extremities. In fractures of that kind we accept a shortening as a means of bringing the proximal and distal parts of the intact marrow tube closely together. In such a case the bone splinters are located around the spot of union just like a jacket. This means in such a case the author uses the same principles as with the treatment of pseudarthrosis which were described in detail in the previous chapter (see illustration 212).



Illustration 212.

- a) Comminuted gunshot fracture in the arm above the elbow.
- b) Intentional shortening of the bone during the the nailing operation.

In order to keep the fragments in place the author recommends bending the nail ends according to the principles developed in the preceding chapter.

In the forearm the marrow nailing may cause the formation of a large block of callus if the destruction is very extensive. In this way any pronation and supination is made impossible. As an example I would like to refer to the case of the 21 year old K.L. We had to deal with an extensive destruction of the radius and ulna which was due to the effect of shell splinters. After the marrow nailing a strong formation of callus with an extensive bone bridge was observed. The bending and stretching of the elbow joint, however, was not hampered (see illustration 213).





a

b

Illustration 213.

- a) comminuted gunshot fracture due to shell splinters in the 21 year old soldier K.L.
- b) After the marrow nailing such a large quantity of callus had developed that any pronation and supination was made impossible.

Such an extensive bridge can either not or only with difficulty be removed operatively so that the question may be asked whether or not in such a case exceptionally a primary removal of all bone splinters from the wound seems to be indicated with the simultaneous union of the fragments by means of one of the methods described in detail in chapter VI in connection with the treatment of pseudarthrosis.

### C. The marrow nailing of infected fractures.

Finally we have to deal with the nailing of fractures in which suppuration has already started. Also here EHR- LICH was the first to nail a considerably infected thigh fracture. He had trusted the complete immobilization of the limb and made the operation with regard to its good effects. He reports about this operation as follows:

"I decided to nail that fracture despite the fact that an extensive suppuration existed which extended even to the vicinity of the bone. The patient tolerated the operation fairly well and



now we were in a position to treat the suppuration with the limb entirely immobilized. We were successful. During the treatment a number of sequestra were cast off, but we succeeded in getting a healing in extremely favorable position".

ZELL was the second to nail a suppurating gunshot fracture. In this way he not only saved the extremity but probably also the life of the patient.

"We had to deal with a four weeks old gunshot fracture of the thigh with septic temperatures and a very bad general condition of the patient. Due to the existence of several decubitus ulcers on the buttocks and spinous process it was not possible to apply a plaster cast. The immobilization obtained with the extension bandage was absolutely unsatisfactory and the patient was in very bad condition due to continuous pains and sleeplessness. After a hypostatic pneumonia had developed we decided to nail the fracture despite the fact that a strong suppuration of the wound existed. It seemed to be possible to obtain an immobilization of the fragments by the nail and with it conditions would be better as to fighting the suppuration and nursing of the patient. During the first two days after the operation the temperatures climbed up to 40°C. After that, however, it slowly decreased by lysis and the general condition of the patient grew much better. One and a half months later the patient no longer had fever and the decubitus ulcers were healed. The nail was extracted 8 months later and after a lapse of 10 months the patient was healed."

HAEBLER asserts that by no other method would a similar good success have been possible. He himself has nailed one suppurating gunshot fracture of the thigh and two suppurating fractures of the arm above the elbow. These he describes as follows:

"In the 4 months old thigh gunshot fracture there existed a 15 cm. long wound on the lateral aspect of the thigh. The bone was partly exposed and the wound was markedly suppurating. Moreover, there existed a gravity abscess in the direction of the adductors. The X-ray revealed that a sequestrum existed. After the nailing the temperature slowly decreased to normal within a week. The general condition of the patient likewise grew much better. He did not suffer pains any more and two months after the operation the wound was closed with the exception of one small fistula. The patient was able to get up and the joints are movable to a considerable extent. According to the X-rays the formation of callus was good and symptoms of an osteomyelitis were not observed. Six and a half months after the operation the nail was extracted.

"The compound fracture of the arm above the elbow had been treated in another hospital. A fragment which still was connected with the periosteum had



erroneously been removed. The wound was sutured with the exception of a small spot for the insertion of the drain and after that the arm was put to rest on an abduction splint. A plaster cast had not been applied. The patient had come to our hospital 3 days after the accident with the wound already suppurating which required an opening of the wound. In spite of the fact that the limb was immobilized with a plaster cast we did not succeed in stopping the suppuration. Again and again gravity abscesses and also a decubitus of the elbow occurred and the general condition of the patient grew worse. Continuous septic temperatures existed and so 9 weeks after the accident we decided to nail the fracture in order to preserve the arm. Due to the existence of a tube abscess which extended to the armpit the nailing operation was made from the distal side despite the fact that with regard to the location of the fracture a nailing from above would have been more suitable. The marrow cavity of the distal fragment was very narrow so that only the thinner nail of the double nail was used. It was driven into the spongiosa of the neck and thus the fracture became absolutely stable. After sprinkling with Marfanil - Prontosil powder the wounds were kept wide open and the arm was put to rest in an arm sling, after a plaster splint had been applied. The same day after the operation the patient was free from pain. The temperature rose to 38.5°C. the day after the operation but it decreased slowly by lysis to normal within 5 days. The general condition of the patient grew considerably better. Within 8 days after the operation the patient started subjecting the limb to exercises with the arm in the sling. Three weeks after the operation the wounds in the elbow had healed and the wound at the fracture cleft was closed with the exception of a fistula. The existing abduction contracture of the shoulder was mobilized 4 weeks post-operatively under narcosis and after that the arm was put on an abduction splint. The temperature did not rise. Eight weeks after this mobilization the fistula was closed and the fracture showed a good formation of callus. After a lapse of 3 months the fracture had come to a bony healing and therefore the nail was removed. The elbow joint was freely movable. In the shoulder joint the arm could be moved upward to the horizontal".

"In the second case we had to deal with a 31 year old prisoner who had suffered a transverse fracture of the arm above the elbow which was due to a pistol bullet passing through the affected part. The patient was brought to our hospital on the 6th day after the wounding with high temperatures and a serious suppuration of the gunshot wound. The entire arm was markedly swollen and red. The fracture was nailed in the open wound from the distal side. After the exposure of the fossa olecrani we observed also here an edema of the entire tissue. The wounds of entry and exit of the bullet were widely opened and after sprinkling Marfanil - Prontosil powder into the wound



a drain was inserted. At the same time the wound at the elbow was kept open. The arm was fixed with a plaster splint. After the operation an increase of temperature up to  $39.1^{\circ}\text{C}$ . was observed which lasted 3 days. After that it slowly decreased to normal. Due to a retention in the wound the temperatures increased again which however decreased after the opening of the wound. Nine weeks post-operative the patient subjected his arm to active exercises and during a changing of the dressing the nail fell out of the wound in the elbow. The fracture was absolutely stable and there existed only a slight impediment of the shoulder and elbow joints. The operation wounds granulated well and only a slight secretion was observed. Fourteen days later several small sequestra located at the fracture cleft were removed. Five and a half months post-operative the patient was released from the hospital. The wounds were healed and the flexibility of the elbow joint amounted to  $70 - 170^{\circ}$ . The shoulder joint was flexible."

M. PASCHER has nailed two cases of compound fractures in the septic phase which were transferred to him for amputation. In one of the cases he achieved a defervescence by crisis and in the other by lysis. In this way both cases healed with the legs in good functional conditions.

BOEHLER declines to nail infected fractures because of the above mentioned unfavorable experiences made with compound leg fractures.

According to MAATZ and REICH compound fractures must be nailed as early as possible. During the phase of the fresh infection, however, one should not nail.

After the early acute symptoms of infection have subsided another period favorable for the nailing develops.

The author has nailed suppurating fractures and pseudarthroses and in none of these cases did fatal terminations occur. We must, however, take into consideration, that only six out of these cases showed very high temperatures. In one case we had to deal with a markedly suppurating thigh gunshot fracture with a knee joint empyema which was referred to in chapter VII A. In the second case we had to deal with a delayed healing of a leg fracture described in detail in chapter VIII. In the four other cases we had to deal with 6-10 weeks old gunshot fractures with marked supuration and fever. In all these cases a good healing was obtained. All the other suppurating cases were nailed during the quiescent phase of the infection which means that the patients had to be free from fever for at least 5-6 days. Amazingly enough the marrow nailing is no serious operation when made during this phase. All measures described in detail in connection with the nailing of fresh gunshot fractures must however be strictly observed, i.e., we must not apply sutures and the wound and the nail insertion site must be kept wide open. In the first place the nailing operation should be made very conservatively especially when treating



suppurating wounds. Special attention must be paid to the possibility of developing abscesses and phlegmons during the period of the after-treatment. Despite the fact that sequestra must be blamed for the developing of the suppuration they should be left in place as long as possible, because of their favorable influence on the formation of callus (see chapter III). Therefore the sequestra should be removed only after the X-ray shows a sufficient quantity of callus. As already mentioned above it will be most suitable to remove the sequestra during the nail extraction operation. The most important factor, however, is to wait until the infection has become quiescent. After that this author waits another 5-6 days during which period the patient must be free from fever and the sedimentation rate of the red blood cells shows normal values. Of 212 cases treated in this way only 3 cases of serious complications occurred. In two out of these three cases the limb had to be amputated and in the third case a resection of the knee joint had to be made. Fatal terminations did not occur.

The occurrence of these three cases is very regrettable. We must, however, say that their number is very small in comparison to the very high number of markedly suppurating fractures. In most of the cases we had to deal with old septic gunshot fractures and the number of complications would certainly have been much higher with other methods. In fact, the percentage was much higher in the cases which were not nailed and which were treated at the same hospital during the same period. A statistical analysis however, is not possible because we had not to deal with very serious cases but with fractures of quite different type which were not nailed because of their shape. In most of the cases the fractures were located near the joints. The total number of these cases was comparatively small during that time because we had tried to nail as many cases as possible.

The total number amounts to 31 cases, the number of fractures and pseudarthroses treated with the nail method amounted to 202 cases, i.e. 87 % of nailing operations were made which proves how many cases can be treated with the marrow nail method (see chapter I). Among the 31 cases of fractures and pseudarthroses treated with the plaster cast method there were 2 amputations.

In spite of the relatively favorable figures given above the author would like to recommend to nail cases of suppurating bone fractures and pseudarthroses only after careful consideration. This is particularly true in cases of extremely high fever. In cases of this kind the marrow nailing should be made only if the fracture cannot be immobilized conservatively. One case of this kind was described above in which the patient could not be kept in the plaster cast any longer because of many suppurating decubitus areas. It is understood that in cases of this kind a "stable osteosynthesis" must positively be obtainable. C. HAEBLER is of the opinion that an operation of this kind should not be made without consideration and that every surgeon should be well aware of his responsibility. HAEBLER's indication however is somewhat more extensive. He



applies his method also to those cases in which due to the existence of sequestra (which must be blamed for the sup-puration) an operative exposure of the fracture site is necessary anyhow. According to his opinion an unsatisfactory position of the fragments of itself is no indication for the marrow nailing.

HAEBLER is of the opinion that it is better to wait until the acute suppuration has subsided and the wound or fistula has come to a healing. Under some conditions which may be due to the war an earlier nailing might eventually be indicated. In all cases in which the patient has to be brought to another hospital it must be kept in mind that the transport is considerably facilitated by the nailing.

This author is of the same opinion. In spite of the favorable course of all nailing operations in seriously suppurating febrile fractures which were published, the total number of cases treated in this way is so small that we are not yet in a position to give a final evaluation. Therefore for the time being, the danger connected with operations of this kind must at least be considered as uncertain.

The situation is different as to those cases in which the inflammation has already subsided. Their total number is much higher and therefore we are in a position to say that in those cases the nailing is not dangerous. The question is now why is the danger only slight in these cases. We do know that a wound is considerably protected against germs as soon as it is covered by a wall of granulation. This, however, cannot be the proper explanation because that wall is penetrated several times during the nailing operation. The true reason may be the fact that a biological balance exists between the bacteria in the wound and the defense forces of the body.

Nevertheless also in these cases greatest care must be taken. In all cases we have to deal with a secondary healing with all its disadvantageous effects. The above mentioned dangers are either eliminated or considerably less marked but the disadvantage of a prolonged healing does not exist. This is in conformity with REICH's findings in connection with the formation of callus despite the fact that at the end we have to deal with the same quantity of callus. Therefore we must be patient with secondary nailings of this kind.

In almost all cases of marrow nailings of this kind during the quiescent phase of suppuration a marked increase of temperature is observed which seems to be most serious, in the beginning. On the first and second day after the operation we observe temperatures of 39°, 40° and higher. The general condition of the patient is not correspondingly affected. A few days later, the temperature decreases either by lysis or crisis.

In some cases, however, a reaction of this kind is not observed at all. In this connection I would like to refer to one case in which we had to deal with a 4 year old





Illustration 214.

Typical temperature curve after the marrow nailing of a markedly suppurating fracture during the phase of quiescent infection. After the marrow nailing (↓) and during the phase in which the patient was free from fever the temperature rises immediately and slowly decreases by lysis a few days later. Sixteen week old thigh fracture in a 26 year old man.

pseudarthrosis after a thigh gunshot fracture with markedly suppurative secretion from a 12 cm. long wound on the lateral aspect of the thigh. During the nailing operation we observed an abscess of the size of a fist which was located at the pseudarthrosis site out of which a cup of pus was drained off. In order to obtain a stable fixation the marrow nail was driven through the knee joint, stiffened by connective tissue reaction. After the operation the temperature was normal (see chapter IX), and the general condition of the patient was in no way disturbed.



Illustration 215.

Temperature curve after the marrow nailing of a 4 year old pseudarthrosis with marked supuration. There existed an abscess of the size of a fist at the fracture site. No increase of temperature after the marrow nailing (↓).

It is a matter of course that also in this case the suppuration lasted a long period of time after the operation, draining especially from the nail insertion site. The suppuration subsided after a lapse of 3 months. It was interesting to note that the suppuration did not extend to the marrow cavity of the tibia into which the nail tip had projected. It is a matter of fact that neither from the



roentgenological nor from the clinical point of view did any corresponding symptoms appear.

The same observations were made in all the other cases of this kind, even in two cases of arthrodesis with knee joint empyema.

From the clinical point of view the secondary healing is markedly delayed after the nailing. On an average the period of hospitalization is twice or three times as high as for primary healing. Moreover in many cases several small operations must be made additionally as for instance the opening of abscesses, phlegmons, removal of sequestra, etc.

Nevertheless, the marrow nailing must be made in many cases during the period of quiescent infection. In cases of this kind this method must be considered to be a great progress as proved in the above mentioned case of the 4 year old suppurating pseudarthrosis. All the time before the patient was either in plaster cast or traction bandage which had caused the stiffening of the knee joint. Several sequestra and a large part of the suppurating area of the bone had to be removed. Callus was not observed at the fracture site. Without applying the nailing method the patient would have had to be kept in the plaster cast until the suppuration had either come to an end or the fistula was closed. All this would probably have taken many months, maybe even years. Maybe that the fistula would not have closed at all. Due to the movements of the pseudarthrosis cleft, which cannot be eliminated with the cast, the infection hardly comes to rest, maybe not at all. After the suppuration has subsided and the wound has healed the patient must be given a term of "safety period" of six months. After that the operation for the pseudarthrosis may be done: Kirschner's splitting, bone suture or application of a large bone graft. Under the condition of a primary healing a further fixation in the pelvic cast would be required for a period of at least 10 weeks. Only after that the patient could start subjecting his leg to exercises. Probably the atrophic thigh musculature would have become more markedly atrophic and probably the already much hampered hip joint would have become entirely stiff, etc. There are many cases of this kind although not as drastic as described above. In case of the femur the time required for the fixation is particularly long, but conditions are similar in other bone fractures. Very often they are even much worse in the forearm. In an arm pseudarthrosis a suppuration which lasts one year with the arm in the plaster cast shows terrible results, as to the function of the hand and the forearm. After this war many a surgeon has prolonged the above mentioned "safety period" to one and even two years in all those cases in which transplanted bone grafts were used. We must, however, take into consideration, that in many cases an additional infection occurs which means that in these cases the bone suture and the bone graft must be removed. This means, however, that everything was in vain.

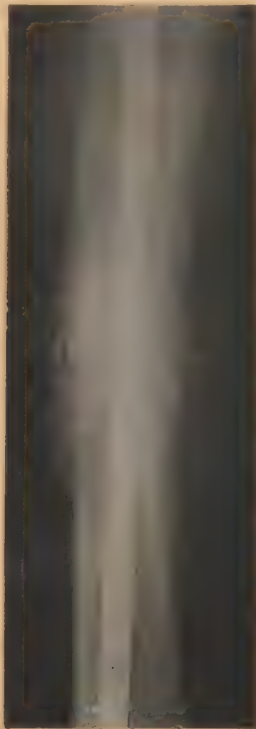
In comparison to that, the above mentioned disadvantages of the nailing during the suppuration are relatively slight



if the operation is made during the quiescent phase. The time of treatment and the "safety period" are not required any more. The fixation bandage must be kept in place until the fever has subsided and the blood sedimentation rate has become normal again. In most of the cases this will be achieved in a few days or weeks. After that the fracture can be nailed. Due to the accurate fixation of the pseudarthrosis achieved with the nail the suppuration quickly subsides and the wound begins to close. After that we may begin subjecting the limb to exercises. The patient may get up and subject his limb to strain even in those cases in which a fistula still exists. In the above mentioned case in which fever had not been observed after the nailing of the 4 year old pseudarthrosis of the thigh the suppuration was very marked during the first three weeks after the operation; but it quickly subsided. With the exception of a small, 1 cm. long fistula at the distal end the wound healed quickly. Six weeks after the operation the patient was able to get up and two weeks later the injured leg was subjected to use (see illustration 216).



a



b



c

Illustration 216.

- a) Four year old pseudarthrosis of the thigh after gunshot fracture with marked suppuration. No formation of callus observed.
- b) the same patient after the nailing.
- c) six months after the operation.



Marrow nailing and the use of Penicillin.

In none of the many thousand cases referred to in this publication was penicillin administered because it was not available. In many cases the patients were given sulfonamides. A local application of sulfonamides is impossible in all closed nailings of simple fractures. In cases of this kind sulfonamides may be administered only by mouth. In case of an osteotomy which is not particularly endangered by infection, sulfonamides should not be applied locally because this author is of the opinion that such a procedure is superfluous and may even be dangerous. In such a case the tissue, the bone and the periosteum as well might be hampered in their vitality and there even exists the danger of necrosis. In such a case we would obtain a culture medium for the germs and thus the intended effect would be changed to the opposite. In fresh gunshot fractures sulfonamides were regularly administered even locally, in the first place we used DOMAGK's Marfanil. HEIM used Globucid by VONKENNEL-KIMMIG. It seems to be much more important however, to administer it either by mouth or intravenously. A real difference between the cases treated with and without sulfonamides was so far not observed. Only the new sulfonamide "Supronal" by DOMAGK shows amazing results. Even in those cases in which penicillin is ineffective or in which it is decomposed this author observed very good results in case of coli and anaerobic infection.

The treatment and the prevention of surgical infections by means of penicillin and Supronal will be quite different from now on. Even the statistics of marrow nail operations will show quite different figures as soon as these drugs are available because the majority of serious complications are due to infection. By using these highly effective drugs most of those complications will almost certainly be eliminated. All cases of marrow nailing which are infected or which are endangered by infection will be treated by means of these new drugs. They will be used either locally or intravenously in all cases of infected fractures. The technique of nailing simple fractures and the osteotomy as well will however, not be changed. The procedure to be applied and referred to in detail in this chapter in connection with infected fractures will not be changed so much. In pseudarthroses in which the suppuration does not subside despite the fact that a sufficient quantity of this medicine has been administered a suture will not be made even in those cases in which this medicine is applied locally during the operation and the wound will be kept wide open. Gunshot fractures of peacetime will be treated in much the same way as described in this chapter. Penicillin inhibits the growth of the bacteria but it is ineffective against the "mechanical" inflammation always developing during the fracture. The very extensive necrosis often observed in gunshot fractures causes an extremely extensive local disturbance of the biological tissue constant. Due to the decay of the kernel a very effective shifting of the ion equilibrium takes place. The ions K and H are rapidly increased. Furthermore a considerable increase of the osmotic pressure etc. occurs and this must be blamed for a further decay of parts of the tissue



which results in a further deterioration of the local conditions. In such a case only an extensive drainage of the secretum will bring relief and will result in a sudden improvement of the condition. The ring of the circulus vitiosus which is so harmful in wounds of this kind is stopped by means of penicillin. The bacteria growing so rapidly in the changed equilibrium and thus causing a constant increase of the deterioration have been rendered ineffective by the use of penicillin.

There is no doubt that the wounds may be much smaller in all cases in which penicillin is used. Only practical experience, however, will show in which way and to what extent all this can be achieved. Practical experiences have so far not been gathered. One thing, however, is absolutely certain: Penicillin will considerably improve the marrow nailing in the sense of an elimination of complications and the indication will be much more extended. LEZIUS for instance has personally reported to this author that he has nailed 500 gunshot fractures with simultaneous administration of penicillin. Penicillin was applied to the fracture site by means of the marrow nail. It was applied at the nail insertion site by using the slit of the nail as an inward drainage. In this way penicillin was brought directly into the gunshot wound. With the above mentioned 500 cases of gunshot fractures only 2 fatal terminations were observed.



## CHAPTER VIII.

### Arthrodesis.

It seems obvious to use the marrow nails for joint fixation too. In 1940 this author performed his first operation of this kind and the results obtained were published. Here the second advantage of the marrow nail method is fully utilized: The stable fixation as well as the fact that fixation bandages are not required. The stable fixation grants a much better security for the bony bridging over of the joint cleft.

In many cases the use of the marrow nail grants another very important advantage. It is only a small operation which eliminates the greater or lesser resection of the knee joint. It will suffice to make a 1 cm. long stab incision above the trochanter and the knee will immediately be stiff. The stiffened knee may be used immediately and the patients are able to walk 3-4 days after the operation. Such an operation takes only a few minutes. There is no loss of blood and no wound shock. This is a very great advantage, for most of the patients in which an arthrodesis must be made, are weakened because of a long lasting confinement to bed. The indication for arthrodesis will be somewhat more extended if a nail is to be used. Otherwise the indications will be much the same as for the other methods.

Arthrodeses have been performed by means of the marrow nail in the:

- |             |   |
|-------------|---|
| A) knee     | B) elbow  |
| C) shoulder | D) ankle joint and the joint<br>between astragalus, calcaneus and scaphoid. |

#### A.) Arthrodesis of the knee joint.

##### Technique.

##### "Open marrow nailing".

Just as in compound and simple thigh fractures two different types of technique must be differentiated: the "open" and "closed" technique.

Applying the open technique means that the knee joint must be opened and consequently this method is used only in those cases in which the knee joint must be opened for other reasons anyhow, as for instance in case of a resection due to knee joint tuberculosis, etc. Therefore the operation begins with this intervention and according to the type of the disease the resection has to be more or less extensive along the lines of Westhues' method. With this method the cartilaginous cover with a thin layer of bone is removed by means of arched sawcuts. The kind of the cut is of no importance and the surgeon may use the method he is accustomed to as for instance the cut running in the transverse direction over the frontal plane of the joint. Esmarch's bandage



may be used. The compression cuff must be placed in about the central part of the thigh. The operation field of the knee joint and the one required for the thigh nailing as well (chapter V c) must be treated with iodine and draped separately. The patient has the same lateral position as with the usual thigh osteotomy. (Chapter VI). The lateral position is somewhat disadvantageous during the resection of the joint because the medial part of the joint is not so freely accessible because it is underneath. This disadvantage may be somewhat counteracted by markedly rotating the leg in the outward direction. After the resection the marrow cavities of the femur and the tibia are opened by means of an awl (chapter Va). This is very easy because only spongy bone has to be drilled through. After that a guide rod is inserted into the marrow cavity of the thigh through the drill hole. After the skin has been pierced through, a knee arthrodesis nail is inserted 8-10 centimeters deep. This process was described in detail in the chapter dealing with the thigh osteotomy. Nails of this kind are 65 cm. long and of different thickness. It was proved by experience that the above length suffices for adults. After that the guide rod is extracted and the nail inserted so deeply that about 2-4 cm. of the nail project from the resection plane of the femur. After that the guide rod is inserted into the marrow nail from the nail head and driven deeply into the marrow cavity of the tibia through the drill hole of the tibia resection plane. In doing so the knee joint must be kept in the proper straight position so that both drill holes stand on each other. After that the nail must be driven in so deeply that only about 3-5 cm. are projecting at the trochanter tip. The joint planes are more firmly pressed together by blows against the sole of the foot. The wounds are either sutured with a rubber drain in place for two days or left open according to whether they are aseptic or septic.

#### "Closed marrow nailing".

The percutaneous marrow nailing of the knee joint is a simple operation. The position of the patient is much the same as with the marrow nailing of the thigh (chapter Vc). The reduction, however, differs very much and in some cases greatest difficulties are encountered. The knee must be brought into a stretched position. In many cases more or less marked subluxations of the leg in the dorsal direction are observed and in cases of this kind the leg must be pressed to the ventral direction. The operation itself is made in such a way that to begin with the 65 cm. long rod is inserted into the marrow cavity of the thigh under X-ray control. After that the knee is reduced by using a screen in two planes. After that the rod is inserted deeply into the marrow cavity of the tibia through the joint. It is recommended to disinfect the skin of the knee and to wrap it by means of a sterile cloth so that an infection cannot occur when the rod penetrates the skin. After that the nail is slipped over the rod as usual (chapter Vc), and driven in. As soon as the nail is firmly seated in the marrow cavity



the rod is removed and then the nail can be driven in so much that only 3-5 cm. of it project at the head of the trochanter tip. The stab incision spot is closed by means of two or three sutures. After the nailing of the knee joint an extremely elevated position of the leg is indicated for a few days for both methods (see chapter II ).

In case of the closed nailing the patient may get up after a lapse of 3-4 days and he may subject the limb to weight bearing. In case of open nailing with resection it is a matter of course that we must wait until the resection wound has healed. In case of a primary healing the patient may get up and subject his limb to weight about 10 days later. Arthrodesis is achieved as soon as ankylosis, that is bridging over by bone, and solidification has occurred. The same effect can be obtained with the nail in any case but with the nail alone it cannot be obtained. In most of the cases, a marrow nail driven through the knee joint does not injure the cartilage planes because it leaves the condyles of the femur and does not enter the cartilage plane of the tibia. In most of the cases the lig. cruciata will be somewhat damaged but they will not be separated entirely. Consequently a stiffening will not occur as long as the cartilaginous planes are intact, which was proved by one case of the Kiel clinic.

A 53 year old man had suffered a 16 months old pseudarthrosis of the femur and a marrow nailing was made by R. MAATZ, after Kirschner's splitting and Beck's drilling had been unsuccessful. Due to the fact that there was in question a fracture near the joint a strong union could be obtained only with difficulty. Thus the nail was driven through the joint and from the very beginning a stiffening of the joint was taken into consideration. In order to obtain a good function of the leg the pseudarthrosis had to be healed. MAATZ was successful. The pseudarthrosis cleft was bridged over by bone so that the nail was extracted 8 months p.op. After the removal of the nail the flexibility of the joint was unchanged. It was, however, somewhat limited before the nailing (see illustration 217)..

All this confirms BOEHLER's thesis that even a long lasting immobilization by the plaster cast does not harm the function of the joints, if it is made in the proper way. The same experiences were made with the nailing of fractures of the neck of the femur. In unfavorable medial fractures many authors and also this author drive the nail through the socket of the hip bone. In general also in cases of this kind a stiffening of the knee joint is not observed after the extraction of the nail. Furthermore, this case proves that it does not mean the disaster of a total loss of the knee joint, if by mistake during the nailing of the femur the rod or the marrow nail are driven right into the joint.

For arthrodesis the evaluation of these experiences shows that with the insertion of the nail an immediate and absolute stiffening and absolute immobilization of the joint and a good function of the leg is obtained, but not necessarily a perfect bony construction. To achieve that we must destroy

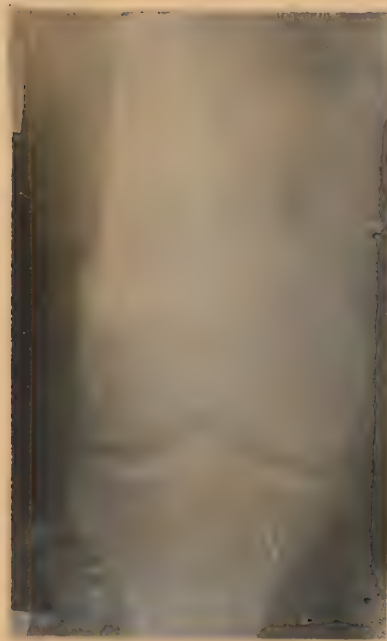




a



b



c

Illustration 217.

- a) Pseudarthrosis of the femur near the joint
- b) same pseudarthrosis after the nailing with the nail driven through the knee
- c) healed pseudarthrosis after the extraction of the nail with the leg in extended position.

the cartilage planes. In case of an open marrow nailing this result is obtained by the resection and in all cases observed a bony union was indeed achieved. In most of the closed nailings the primary disease usually will already have caused such a destruction or will cause it later. In case of a luxation of the knee joint which lasts years, such a damage of the cartilaginous cover will very often exist. In many cases a bony bridging over cannot be obtained without a second operation. Also in this case of an arthrodesis by means of the marrow nail two operations are quite possible and useful. Most of the patients were confined to bed for years and consequently they were rather weak. By means of the relatively small operation they are able to get up and to walk. The second operation is made later as soon as the general condition of the patient has grown better. We may even wait as long as 1-2 years if a bony union was not yet obtained. In old people it will be better to desist from that second operation and to leave the nail in place. The conditions are similar in inoperable tumors (see chapter X). In all the other cases the second operation may also be very small. We did not try to apply liquids of strong irritating effects into the joint as for instance iodine tincture. This seems to be rather dangerous. It is most suitable to destroy the cartilaginous planes of the joints by means of a small chisel in the way of Kirschner's splitting as demonstrated by illustration 218. For this purpose a small incision must be made into the femur condyles.

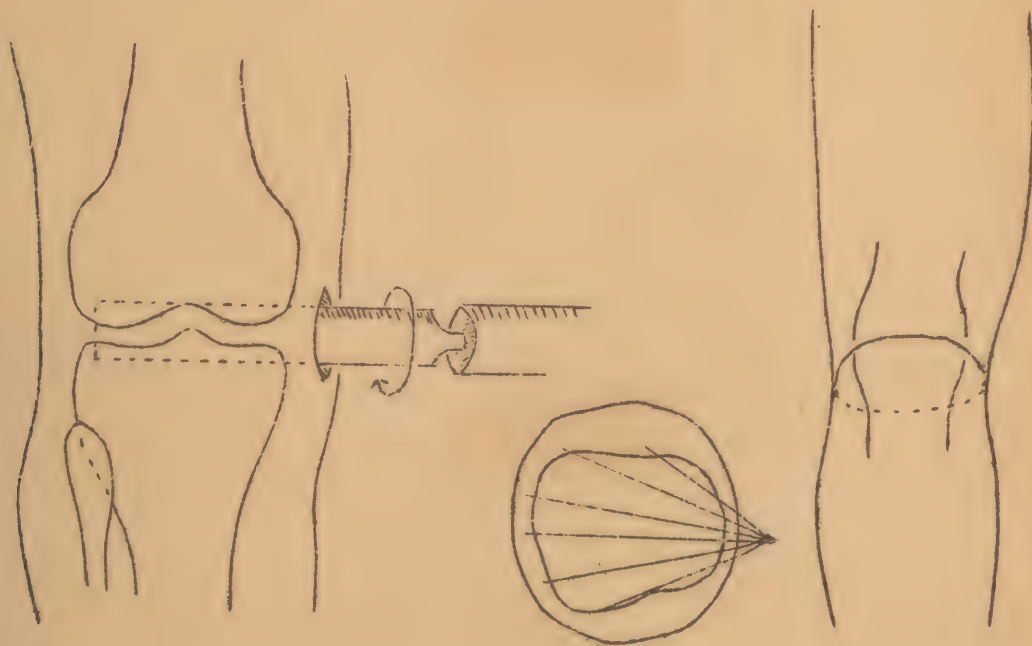


Illustration 218.

Second phase of the closed knee arthrodesis by means of the marrow nailing. Destruction of the cartilaginous planes by means of a drill or a chisel from the site of 2 stab incisions.

It seems to be most suitable for this operation to detect the precise position of the articular space of the



knee before the operation by means of the fluoroscopic screen and turning the leg to all sides. The articular space is drawn upon the skin as precisely as possible in the form of a ring around the knee joint. The skin incision is made in such a way that the surgeon cuts through this ring vertically with the skin incision 3 cm. long. The skin must be cut through to the bone, with the cut either on the medial or lateral surface. The lateral surface is more convenient for the surgeon and a flat chisel 2 cm. wide seems to me most suitable. Electric drills may cause heat necrosis. This chisel is driven in in such a way that its edge corresponds to the longitudinal direction of the leg, i.e. it runs vertically to the cartilaginous planes. It must be driven in 5-7 times so far that it is palpable below the skin on the opposite side. It is a matter of course that it must be palpable precisely below the marked line. Furthermore it must not be driven in so much to the dorsal aspect that the arteria poplitea is endangered and damage to the nail should be avoided. It is not necessary to make this operation while a tourniquet is applied. The danger of an extensive damaging of the nail does not exist because the power of resistance of the material used for the nail is much too great. An intervention of this kind may be repeated several times.

The marrow nail arthrodesis of the knee joint was made by the author in the reversed succession. In another hospital resections had been made which, however, in the cast did not result in consolidation. In this case the cartilage was destroyed first and then the marrow nailing was made.

#### Mistakes with the open and closed marrow nail arthrodesis of the knee joint.

In the first place we have to take into consideration all those mistakes which occur with the marrow nailing of the thigh fractures (chapter VI B and V ) because the marrow nailing operation of the knee represents, so to speak, a special kind of nailing.

In cases of a more marked physiological curvature of the femur the nail may leave the marrow cavity in the ventral direction and penetrate the planum popliteum of the femur. If this occurs it is noticed immediately by the fact that the nail tip may be palpated beneath the skin. As long as the skin is not perforated this has no harmful effect. Such a mistake can easily be corrected. The nail is extracted for about 10cm. and after that the guide rod is inserted distally in cases of open nailings and proximally in all closed nailings. A mistake of this kind cannot occur at all if in the very beginning the rod which runs in the proper direction is not extracted after the nail was driven in a few centimeters. (Chapter V and VI B). In this way, however, the insertion of the nail is more difficult because the friction of the nail is considerably increased. The planum cannot so easily be perforated by the guide rod which

is inserted manually. This is particularly true if the rod is inserted with rotation when meeting an obstacle. The danger is much greater, however, that the nail or the guide rod may protrude from the tibia head either laterally or ventrally. If this occurs it will be palpable underneath the skin. In all marrow nailings of the knee we must take care that an exact reduction is obtained, i.e. that the marrow cavity of the tibia runs in the prolonged axis of the femur. Small deviations may be counteracted by the fact that near the knee the marrow cavity of the tibia is shaped like a funnel. In most of the cases the knee is not extended enough or the subluxation of the tibia in the dorsal direction which is not sufficiently counteracted is often observed after a long confinement to bed. A protrusion of the guide rod and of the nail into the hollow of the knee and in this way causing injuries of the vessels and of the nerves is not possible because the guide rod and the nail will work their way along the front plane because of the physiological angulation of the thigh. The above described mistakes may easily be corrected by withdrawing the nail a little and correcting the reduction.

#### Disadvantages of the marrow nailing of the knee.

The only disadvantage encountered with the marrow nailing so far was the fact that the knee could be stiffened only in an absolutely straight position, i.e. with an angle of  $180^{\circ}$  and in this way the function was somewhat hampered. This disadvantage was however taken into consideration due to the other advantages of this method. In 1946 this author has eliminated even this disadvantage by using a slightly angulated marrow nail with a correspondingly shaped guide rod (see illustration 219).



Illustration 219.

65 cm. long curved knee arthrodesis nail with guide rod (the radius of the curvation amounts to 100 cm.)

When using this nail the knee stiffens in the generally most favorable position of  $170^{\circ}$ . The bending of the nail amounts to almost the physiological bending of the thigh. Consequently its insertion is no more complicated than the insertion of a straight nail.



Arthrodesis of the knee with an angulated marrow nail.

With the open marrow nailing arthrodesis of the knee joint as for instance in cases of resection of the joint due to tuberculosis the straight and the angulated nail as well may be used because after the resection the knee may be brought in any desired position. The same conditions prevail in closed arthrodesis in typical wabbling knees with loose lateral ligaments.

If we want to nail a joint with tense lateral ligaments, as for instance in arthrotic knees with only slight but very painful function, a nailing by means of a straight nail may even be impossible because of the physiological valgus position of the knee. In such a case the nail tip would protrude at the medial aspect of the tibia head (see illustration 220).

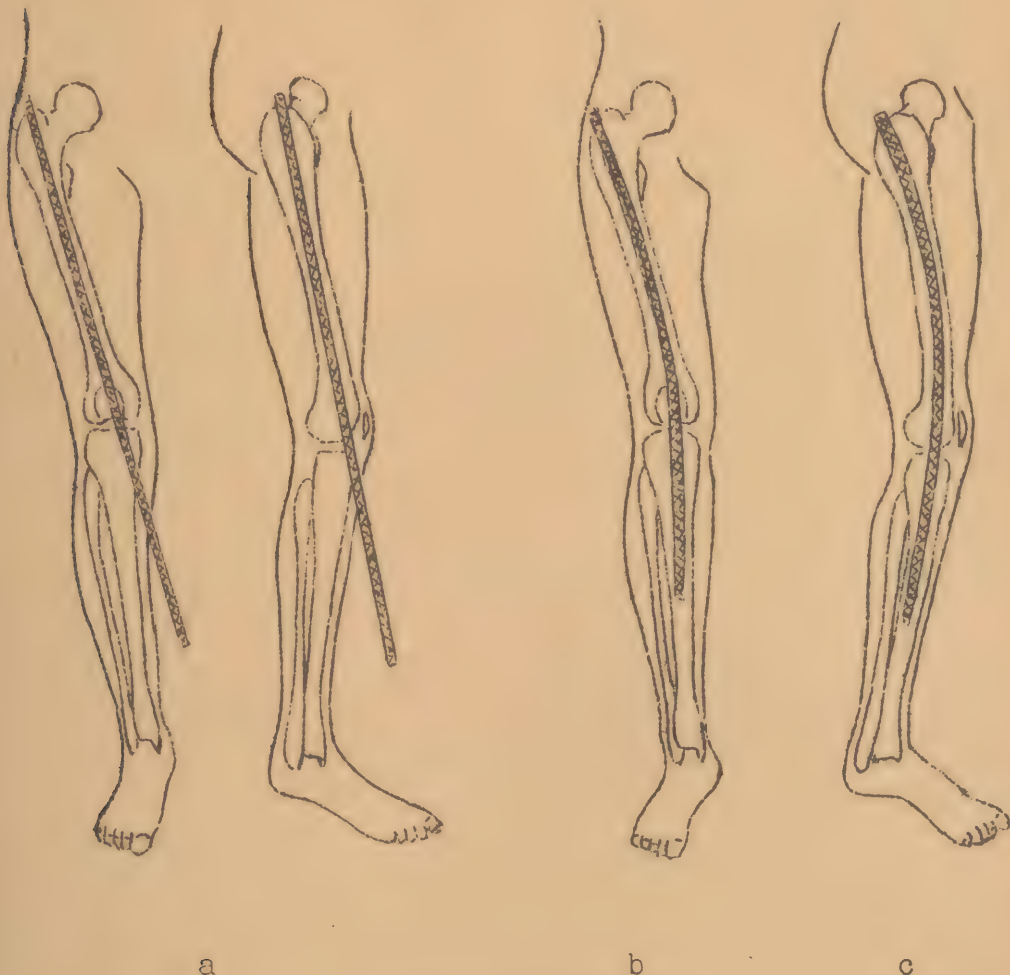


Illustration 220.

"Closed" arthrodesis of the knee joint.

- a) a straight marrow nail cannot be used because its tip would protrude medially from the tibia head because of the physiological valgus position of the knee joint.
- b) good results are obtained by using angulated nails
- c) lateral aspect; the nail must appear as a curved line in both planes, In this way the joint becomes stiff with the desired slightly angulated position.

All this can be prevented by using curved nails. When inserting nails of this kind care must be taken that the curvature plane is in the right position. The tip of the nail must point outward and in the dorsal direction.

Supracondylar osteotomy and knee arthrodesis according to HOFFA.

In many cases of old contraction deformities rather strong forces are required for the mentioned (screw) apparatus. We must, however, see to it that those forces are not too strong in order to prevent serious damages of the vessels and nerves. Thus in many cases shortened flexor tendons are separated by means of the tenotomy. Also in cases of this kind two operations are indicated in order to decrease the danger of infection. During the first operation the sinews are separated and 10-14 days later the nailing operation is made. HOFFA's supracondylar osteotomy is very recommendable. It was referred to in chapter VI as an example of an ideal osteotomy. The operation is small, it does not last long and the periosteum is spared. After a skin incision which runs in the longitudinal direction the chisel is inserted through the musculature so that it touches the bone. After that the instrument is turned round but it must not lose its contact with the bone. Then the chisel is driven deeply into the bone by strong blows and the bone is broken by bending the leg inward. After that we must extract the chisel and suture the skin of the wound. It will be most suitable however, to drive the rod or the nail into about the middle of the femur from the trochanter before the operation. Immediately after the skin suture was made they must be driven into the knee joint under X-ray control. The correction of the position of the knee joint is made during the osteotomy separation. In those cases in which a straight nail is indicated the leg may easily be pushed to the medial side.

Knee arthrodesis with the femur nail. Normal length.

In those cases in which 65 cm. long straight or angulated marrow nails for the knee are not available, 40-42 cm. long thigh nails may be used. Such a marrow nail is inserted as deeply as possible in the usual way from the trochanter tip. After that a shorter nail, 20-25 cm. long is put on it and driven in. Due to the physiological angulation of the shaft of the femur the knee joint will become stiff in a slightly angulated position (see illustration 221).

The shorter nail is extracted first in the usual way. After that a hook is driven into the bed of the shorter nail and in this way the second nail is removed. It is more simple of course to use 65 cm. long marrow nails.





Illustration 221.

Knee arthrodesis with a thigh nail of normal length. A second shorter nail is slipped over it in order to facilitate its extraction.

Indications for the marrow nailing of the knee.

1. Fresh knee injuries:

Primary marrow nailing is indicated in cases of markedly split up tibia heads when due to an accident the joint planes of the knee are so much damaged that at least a limited function of the joint cannot be restored. It will be suitable, however, to wait very long with an operation of this kind according to the directions given in connection with shock (chapter IV) because of the danger of fat embolism. Consequently the leg must be put at rest on a splint for some days or weeks and only after that should the marrow nailing be made. The conditions are similar in fresh war injuries of the knee. Due to the fact that cases of this kind have not been available this author has so far not yet nailed cases of this kind. In only one case of a several weeks old gunshot injury of the knee was a marrow nail used by this author. This case is referred to in the following examples (S). Resections due to tumors and tuberculosis show good results because in cases of this kind the nail replaces the plaster cast.

## 2. Old injuries and diseases of the knee.

Very frequently we have to deal with contractions which are due to lack of nursing, badly healed tibia head fractures or untreated luxations. In cases of this kind a healing by means of the plaster cast can either not be obtained or the joint would become stiff. These cases are indicated for the nailing. According to the experiences of this author very frequently contractures of this kind can be eliminated in one operation by means of the osteoclasis described by RIZOLI or PHELPS-GOCHT by using strong forces. It was proved, however, that it is not possible to hold the reduction in place by means of the plaster cast because of the strong contraction force of the muscles and tissues. An effect of this kind can be obtained only with the marrow nail. Finally all those types of loose knees are indicated for marrow nailing in which the flexibility of the joint is negligible. In most of the cases joints of this kind are extremely painful but with the use of a closed marrow nail this painfulness subsides immediately. This is also true for all cases of serious arthrosis deformans. The question arises whether or not the marrow nailing is indicated for the immobilization of an infected knee, i.e. in case of an empyema. An operation of this kind was made once by this author in the above mentioned gunshot fracture. So far as I know no other surgeons have ever tried such an operation. In all these cases we have to deal with infections which are accompanied by high fever. In conformity with the directions given in chapter VII this author would nail cases of this kind only exceptionally because the not yet infected marrow cavities of the femur and tibia must be opened during the operation.

### Examples for the different types and indications for the marrow nail arthrodesis of the knee joint.

In one single special case with high fever and bad general condition this author decided to nail the knee.

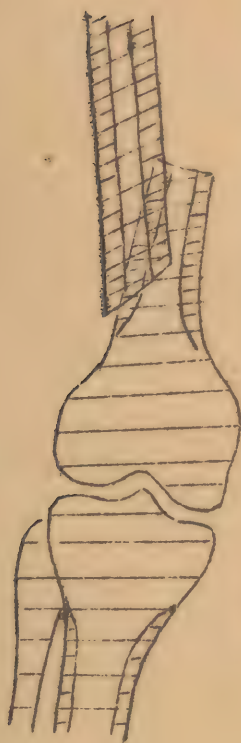
The soldier K.M. was 36 years old and had suffered a wounding due to shell splinters.

Findings: Opening of the left knee joint. Fracture of the femur a hand's breadth above the knee joint (see illustration 222), large ragged wound at the lateral aspect of the thigh and knee. At the main dressing station a wound revision and a knee joint suture had been made. Reduction of the fracture and fixation by means of Kirschner wire which were led through the condyles, head of the tibia and heel. Pelvis cast. A serious infection of the fracture and of the knee joint occurred. Resection according to LAEWEEN. Nevertheless the temperatures were constantly high and amounted to  $41^{\circ}$  for some time. The fragments slipped while in the cast (see illustration 222). Consequently the plaster cast had to be removed because of the presence of abscesses underneath the skin of the spinous processes, lumbar vertebral column, the os sacrum, both trochanters and the calf of the leg. Furthermore a tube abscess had developed from the fracture site. The surgeon sent the patient to this author to decide the question whether the



limb should be amputated or a marrow nailing should be made. This author decided to perform a nailing operation. The operation was made under Evipan anesthesia. In the usual way the guide rod was inserted into the trochanter from the wound above the fracture. After that a 65 cm. long straight nail was inserted into the fracture and from there into the knee joint. In this way difficulties were not encountered, because the knee was already exposed due to the resection. A splint was not applied (see illustration 222).

After a lapse of 6 weeks the fever had slowly decreased to normal and all abscesses were healed. The patient was able to get up and six weeks later he was transferred to a hospital in the home territory. Here the fracture came to a good healing and the knee joint was bridged over by bone.

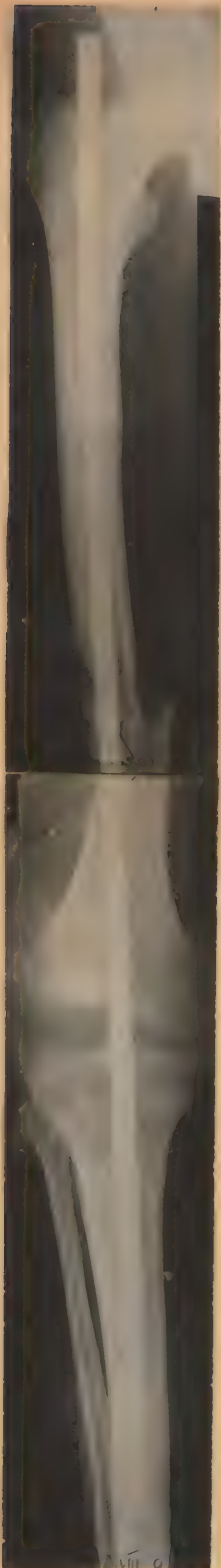


a

Illustration 222.

- a) Fresh gunshot fracture in the left thigh with opening of the knee joint.
- b) same case after the knee joint resection and marrow nailing.
- c) same case a few months later.

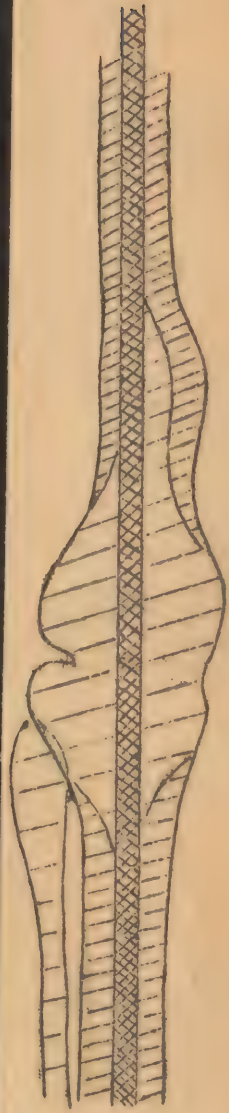
(Illustrations 222b and c see next page).



222b



222c



As a further example of an open marrow nailing I would like to refer to the case of a 68 year old woman patient M.H. She was in very bad general condition and had suffered from an arteriosclerosis, and arthrosis deformans of the hand, shoulder, elbow and knee joint since



1930. She had to be confined to bed because of the painfulness of her left leg. Her left knee showed a marked bending and could not be moved, even when using strongest forces. The X-ray showed an irregular limitation of the joint planes and arthritic spicules (see illustration 223).



a



b



c



d

Illustration 223.

- a) Marked contraction deformity of the left leg due to an arthrosis deformans in the 68 year old woman patient M.H.
- b) Same knee after resection and marrow nailing
- c) Same case six months later
- d) X-ray of the preparation after the extraction of the nail.

On June 29, 1946 a resection of the knee joint was made under lumbar anesthesia and the frontal plane of the joint was incised in the transverse direction. Conservative resection by arched saw cuts. Suture in layers with drainage of the wound (see illustration 223). Unfortunately an infection of the wound occurred and the patient suffered from fever after July 10. On July 18, an abscess the size of an egg at the nail head was opened which resulted in an abundant drainage of pus. A very extensive infection of the resection wound of the knee was observed and on July 29 an abscess of the right elbow had to be opened. The temperature rose to 39°C. with extremely marked suppuration. On September 24, another revision of the nail insertion site was made which did not reveal any specific findings. After that time the temperature was normal and the drainage slowly decreased. On November 11, 1946, the patient was able to get up. Her general condition had considerably improved. The hemoglobin values had increased from 45% up to 52%. In the beginning of December 1946 the wounds were almost closed and the drainage was very slight. The X-ray (see illustration 223d) showed a good structure of the bone. On December 18, 1946, the patient suddenly suffered a strangulation ileus. Immediate operation under spinal anesthesia. Fatal termination due to circulatory failure.

This case is another proof that despite a serious infection general osteomyelitis does not occur and that the wounds do come to a healing with the nail in place. Infections of this kind can be limited considerably and the operation be much smaller in closed marrow nailings. In a similar case of a 48 year old woman patient E.S. who was in poor general condition the knee was straightened by using the osteoclast of Phelps-Gocht after a "Quengel"-cast had been applied unsuccessfully. The reduction was possible only by using strong force but we did not succeed in keeping the knee in a straight position with a plaster cast. Therefore, on 1 August 1946, a closed marrow nailing of the knee was made under Evipan anesthesia during which the osteoclast was attached with ease. The operation lasted only a few minutes. The X-ray (see illustration 224) proves that we had to deal with an old untreated dorsal subluxation of the right knee which was caused when the patient had slipped on a stairway in March 1946. The patient was kept in bed. Due to the fact that long arthrodesis nails were not available, a 42 cm. long thigh nail was used (see illustration 224b) and a second short nail was placed upon it. The extraction of the nails was made in such a way that the short nail was extracted first and after that a retraction hook was inserted into the bed of the nail. In doing so, it is not difficult to find the eye of the long nail and then to extract that nail.

Despite the fact that the patient had been confined to bed for 5 months, she was able to get up three days after the operation and subject the limb to weight bearing. No harmful effect of the operation was detected. A bony bridging over of the knee was not observed 9 months after the operation despite the fact that the patient had intensively subjected the limb to exercises (see illustration 224 c). Consequently, on January 15, 1947, the cartilaginous planes of the knee joint were destroyed by using a chisel with the patient under lumbar anesthesia (see illustration 224 d).





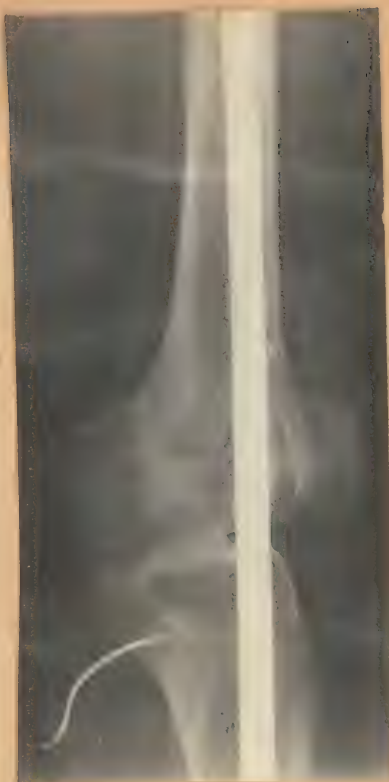
224a



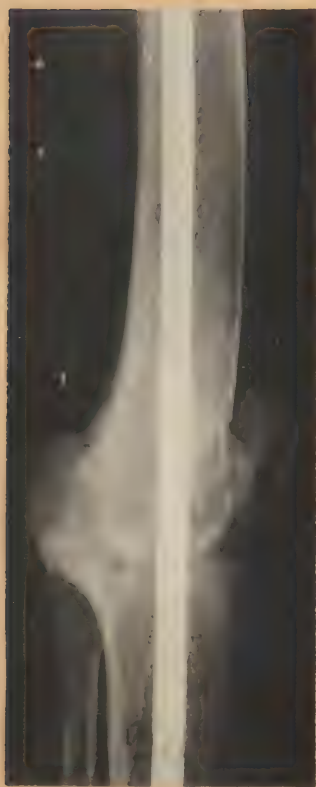
224b

Illustration 224.

- a) Old subluxation with angulation of the knee joint in the 48 year old woman patient E. S.
- b) same knee after closed marrow nailing using 2 nails
- c) after a lapse of 9 months no bony union observed
- d) after the splitting up of the joint planes. (Illustrations 224c and d see next page).



224c



224d

The 19 year old woman patient E.L. had suffered with a tuberculous granulation tissue growth of the right knee joint since the summer of 1946 (see illustration 225). On September 30, 1946, a biopsy was made which confirmed the above diagnosis. On November 5, 1946, a resection of the joint was made. This operation revealed that we had to deal with an enormous fungoid thickening of the synovia and a tuberculous caries of the femoral condyles. During this operation a tuberculous ball sequestrum was removed. Unfortunately much of the condyles had to be resected. After that the marrow nailing had to be made by using a slightly curved marrow nail (see illustration 225). Healing then took place without com-

plications, so that the patient was able to get up 10 days after the operation and to subject the limb to weight bearing. The nail was removed on February 6, 1948 (see illustration 225c).





a



c



b

Illustration 225.

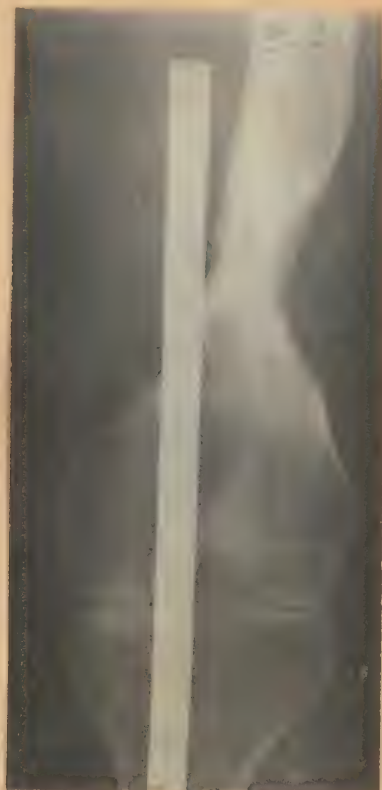
- a) Nineteen year old patient E. L. knee tuberculosis with caries of the femoral condyle
- b) after the resection and marrow nailing by means of a slightly angulated marrow nail. The nail extends from the trochanter down to the vicinity of the ankle joint
- c) after the extraction of the nail, three months later.

The knee is, so to speak, entirely bridged over by bone and in a slightly curved position. The angle amounts to  $170^{\circ}$ . The knee itself is also in a somewhat bandy leg position which, however, is insignificant.

Finally I would like to refer to a nailing operation of a loose knee. On August 17, 1944, the 40 year old patient R.H. suffered a gunshot fracture due to shell splinters which was located just above the femoral condyles of the left side with a large wound on the lateral aspect of the thigh. The fracture was healed in the plaster cast after extensive and long lasting suppuration. The knee was almost stiff and only slight wobbling movements were possible. Consequently the patient could not use his leg anymore. (See illustration 226). On September 5, 1946, the knee was marrow nailed. Due to the fact that the knee had healed in lateral displacement a typical marrow nailing from the trochanter was not possible. Therefore we decided to make a small stab incision into the front plane of the thigh with the patient under Evipan anesthesia. The distal fragment was opened by means of an awl and a marrow nail driven through the knee (see illustration 226b). From that very moment the patient did not complain about pains anymore and he was able to subject his limb to weight bearing four days after the operation. Another possibility would have been to open the old fracture and to nail it in the typical way first of all because the fracture was healed with a slight inward rotation. Due to the bad condition of the area of the wound however, a reactivation of the infection would certainly have occurred. The further course of the disease proves how well founded this reflection



226a



226b

(Text to illustration  
see next page).





c



d

Illustration 226.

- a) 40 year old patient R.H. Healed gunshot fracture of the femur which is laterally displaced and rotated inward. Painful loose knee.
- b) Marrow nailing by means of a stab incision from the distal fragment. Patient is immediately free from pain but after a lapse of 9 months no consolidation was obtained.
- c) Splitting up of the joint planes.
- d) After the extraction of the nail twelve months later. Consolidation.

was. After a lapse of three weeks another marked suppuration of the old wound on the lateral aspect of the thigh occurred, which lasted five weeks. The new operation wound and the tissue around the nail did not get infected. Also here a bony bridging over was not observed. Three months later slight wabbling movements again (see illustration 226c). Consequently a second nail was inserted 20 weeks later and at the same time the joint planes were split up. (See illustration 226d). After a stable bony bridging over had been obtained, the nail was extracted after a lapse of 1 year. The position of his foot which was rotated inward did not present a considerable hinderance to the patient. In order to eliminate that position a rotation osteotomy of the leg would have been indicated. Its fixation would have been guaranteed by the knee marrow nail.

3. The marrow nailing of the upper and lower foot joint.

The nailing of the upper and lower foot joint cannot be considered to be a true marrow nailing, because only the proximal part of the nail is seated in the marrow cavity with the distal part in the spongy tissue. Just as in nailings of the neck of the femur also here a loosening of the nail must be taken into consideration. Consequently the results obtained are much worse. The arthrodesis of the lower foot joint can strictly speaking be considered to be a true marrow nailing only in those cases in which the nail also runs through the upper foot joint, i.e. it must project into the marrow cavity. If we nail only the lower foot joint the nail is seated only in the spongy tissue of the talus and calcaneus. Nevertheless I would like to refer to the following example of such a case in order to give a complete picture.

The 17 year old patient G.E. suffered from marked pes equinus with an outward rotation of the foot which is due to an old infantile paralysis (see illustration 227).



a



b

Illustration 227.

- a) Marked pes equinus with external rotation.  
Patient G.E. before the operation
- b) After the operation.

On July 25, 1946, an operation was made with the patient under ether anesthesia. Tenotomy of the Achilles tendon was performed according to VULFIUS. Just below the central ankle bone an incision was made which extended to the middle

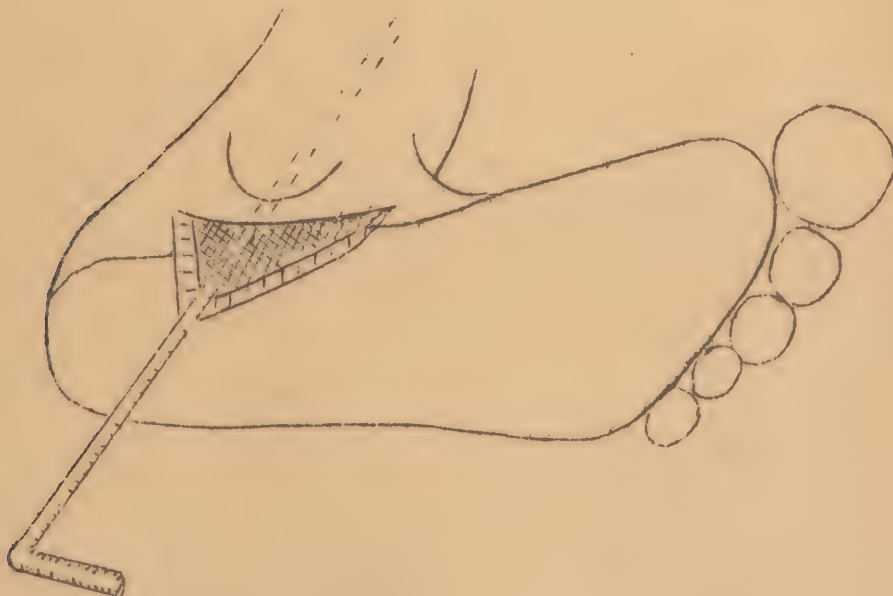


line of the foot and from there to the end of the foot. The tendons were laid aside and the lower foot joint was exposed. After that a wedge shaped resection was made. From the lateral wound angle a Kirschner wire was drilled through the talus in the direction of the heel so far that it pierced the skin of the heel. After we had made several attempts we succeeded in getting it out precisely in the center of the heel. In this very simple way a precise control of the position of the nail is obtained. Moreover, the site of insertion of the nail in the wound is well established. After that a Sven-Johannson-nail (Smith-Petersen nail) was slipped over the wire and driven in. (See illustration 227b). An ankylosis of the joint in the desired position was obtained and the nail was removed 12 weeks later.

Due to this operation only the lower foot joint became stiff, the upper foot joint was absolutely flexible. More frequently, however, we have to deal with a stiffening of both foot joints. The indication is the same as in the arthrodesis of the knee joint. The bad position of an already existing ankylosis must frequently be transformed into an ankylosis with good position. The foot joint is healed either in pes equinus or heel-foot position or it is angulated inwards or outwards. A faulty position of this kind can be counteracted by cutting a wedge out of the foot joint. For this purpose we preferably use a chisel because we have to deal with spongy bone. But also the special saw described in detail in chapter VI B seems to be very useful. The technique to be applied for the insertion of the nail is as follows:

A skin incision 4-5 cm. long must be made about 1-1½ cm. proximal from the sole edge parallel to the sole plane. This incision is located distally from the medial ankle bone. After that we work our way bluntly to the plane below the calcaneus where the tissue is pushed aside for a few centimeters by a raspatory. After that the femur guide rod is inserted into the distal end of the osteotomy site. In this connection it is of no importance whether the osteotomy site which depends on the location of the wedge to be cut out is above or below or on the medial or lateral aspect. In all cases it will be possible to bend the foot after the wedge has been cut out at the osteotomy site so much that an easy insertion of the nail is possible. And now the most important thing to be observed: The guide rod must be driven through the foot joint, talus and calcaneus in the precise direction, i.e. precisely vertical to the foot sole. In marrow nailings there is only one right position and that is the direction of the marrow cavity as is well known. In the spongy tissue of the foot bones as well as in the neck of the femur most any direction of the nail is possible and it is very important to determine the right one. For this purpose we put a plate on the sole of the foot and when inserting the guide rod it must always run precisely vertical to this plate. During the insertion process under direct vision a broad raspatory is inserted deeply into the wound of the foot. As soon as the guide rod has penetrated the bone it cannot pierce the skin of the sole of the foot because of the raspatory. After that the skin of the sole of the foot is

pulled aside and held there laterally with the raspatory. The raspatory finds sufficient hold on the rod and in this way it cannot slip so easily from the smooth surface of the calcaneus. After that the guide rod is inserted a few centimeters more deeply so that it is a few centimeters above the level of the sole of the foot. After that the nail is inserted. So far we have frequently used 10-15 cm. long thigh nails. The nail after having been slipped over the guide rod is inserted so deeply that it appears at the osteotomy site. It should project from the bone by about  $1\frac{1}{2}$  cm. After that the guide rod is extracted. After the osteotomy site has been reduced the nail tip is slipped into the marrow cavity of the proximal fragment. The nail must be driven in so deeply that its head projects at the calcaneus for only 1 cm. According to the experience of the author this is of no particular harmful effect when walking because the sole of the foot is thickly padded with fat. If a precise reduction can be obtained only with difficulty it seems to be suitable to insert the guide rod from the head of the nail and to drive it deeply into the marrow cavity of the proximal end. Only after it is proven that the guide rod is really in the marrow cavity the nail is slipped over the guide rod and is driven into the above mentioned position. The skin of the sole automatically closes over the nail head as soon as the raspatory is removed from the wound. This method corresponds to Lexer's method of arthrodesis of the foot joint by means of a graft. According to Lexer's method, however, the skin of the sole must be pierced. This author prevents that by means of the above described technique because wounds at that particular spot frequently show harmful effects (see illustration 228).



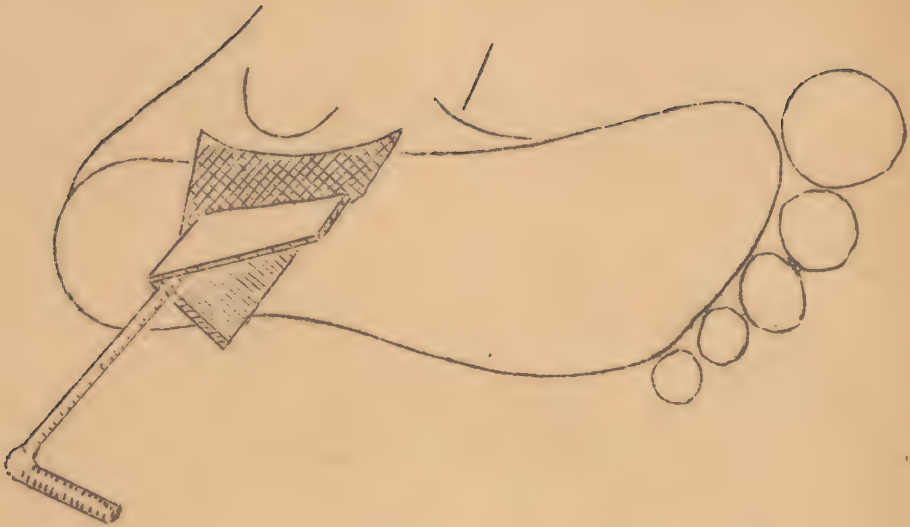
a

Illustration 228.

Technique of the marrow nailing of the ankle joint and the joint between astragalus, calcaneus and scaphoid.

- a) the guide rod is inserted vertically to the plane of the sole of the foot.
- b) the skin of the sole of the foot must be held aside. (Illustr. 228b see next page).





228 b.

Mistakes with the marrow nailing arthrodesis of the foot joint.

The foot is stable but it is not in the desired position. This is due to the fact that the guide rod was driven in in the wrong direction, i.e. it did not run vertically to the plane of the sole of the foot. Counter measure: The nail must be extracted (chapter V) and the guide rod inserted again in the right direction from the osteotomy site.

Mistakes: The faulty position was compensated but the foot is rotated either medially or laterally.

Counter measures: In this case it will suffice to insert a guide rod from the insertion site and to extract the nail through it. After that the foot is brought into the correct position and then the nail must be driven in again.

Further mistakes: The foot is in good position but at the site of the osteotomy it is loose or it can be rotated. The nail is too thin.

Counter measures: Extraction of the nail as described above, insertion of a thicker nail.

4. Disadvantages of the marrow nailing arthrodesis of the foot joint.

As already pointed out we do not have to deal with a true marrow nailing and just as in the nailing of the neck of the femur there exists the danger of a considerable loosening of the nail. In this way the osteosynthesis is

no longer stable. Thus the principles of the marrow nailing do not prevail anymore so that the development or the growing worse of an already existing pseudarthrosis must be taken into consideration. In cases of this kind we unfortunately are obliged to apply an additional fixation bandage. In order to avoid disadvantages of this kind this author has constructed a conically shaped nail with a wing-like broadened head (see illustration 229).



Illustration 229.

Marrow nail for the foot joint arthrodesis with markedly broadened head.

Examples for the osteotomy of the talipes equinovagus.

On April 1st, 1944, the 21 year old D.W. suffered a gunshot fracture of the right leg a hand's breadth above the ankle joint with paralysis and numbness of the foot. Serious infection developed which required the opening of numerous abscesses. Application of a window cast. The ankle joint and the joint between the astragalus, calcaneus and scaphoid became stiff with the foot in abduction. Moreover a slight pes equinus position was observed (see illustration 230). The toes were stiff in dorsal flexion and at the tip of the big toe an ulcer the size of a pea is observed. There was a hyperaesthetic zone at the instep. A fistula on the lateral aspect of the foot joint with an external opening the size of a pea, 2x2 cm. large fistulae in the soft tissue on the 5th toe. With the patient in this condition on June 27, 1946, an operation was performed. The patient was under ether anesthesia. The skin incision was made in the transverse direction over the frontal plane of the foot joint somewhat bowl-like round the lateral malleolus. During the exposure of the malleolus special care was given to the tendons. At the front and lateral aspect of the foot joint a wedge shaped incision was made. After that a marrow nailing was performed as described above (see illustration 230b). The wounds were not sutured and only a slight infection of the wound occurred with a slight increase of temperature. The other secretion from the wounds becomes more marked during

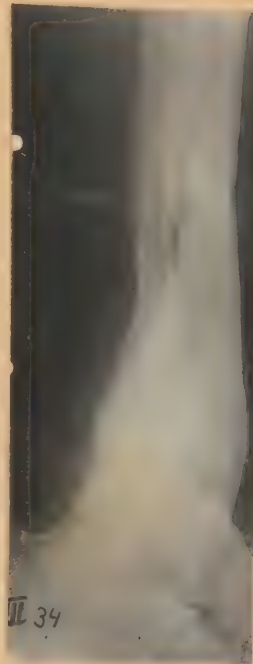




a



b



c

Illustration 230.

- a) D.W. 21 years old, old gunshot fracture with fistula. The foot joint is in abduction and the pes equinus is slightly stiff.
- b) same case after the marrow nailing and wedge osteotomy.
- c) after the extraction of the nail, 6 months later.

the following weeks. On July 17 a gangrene of the first and fourth toe was observed which was considered to be due to trophoneurotic disturbances in connection with old injuries of the vessels because during the marrow nailing larger vessels had certainly not been injured. During the following treatment the nail became somewhat loose. The foot wobbled at the osteotomy site but it became stable after a Braun's splint had been applied. The foot was angulated in an outward position of about  $10^{\circ}$ . This position is not too bad. The pes equinus position was eliminated. Extraction of the nail and amputation of the toes. On December 3, all wounds are healed (see illustration 230 c).

Examples of a talipes equinus osteotomy.

The patient K.H.L. was 19 years old. He had suffered a shell splinter injury of the right ankle joint on April 4, 1945. He was treated with the plaster cast. The ankle joint and the joint between the astragalus, calcaneus and scaphoid were stiffened by bone and a marked pes equinus position was observed. (See illustration 231). Marrow nailing and osteotomy as described above on 18 May 1946 (see illustration 231c). During the operation several fistulae existed on the lateral aspect and inner aspect of the foot joint and the sole of the foot. No fever and no increased sedimentation rate. In the second week after the operation the fever rose to  $39.2^{\circ}$  but after that the temperature was normal. The secretion of the fistulae became less marked during the following weeks. On June 9, 1946, the patient got up despite the fact that fistulae still existed. The fracture became stable and was in good position. Wobbling movements were never observed. Removal of the nail on September 17, 1946. (see illustration 231c).



a



b

Illustration 231.

- a) Patient K.H.L. 19 years old. Stiffening of the right foot joint with marked pes equinus position.
- b) after the marrow nailing
- c) after extraction of the nail 4 months later (illustration 231c see next page).





231c.

The same method was used in cases of deeply located pseudarthrosis of the leg if the ankle joint and the joint between astragalus, calcaneus and scaphoid were stiff (see chapter VI, F.).

#### 5. Marrow nail arthrodesis of the hip joint.

The indications are much the same as in the knee joint. But there are also other operations which should be taken into consideration as for instance the plastic surgery of the hip joint or the subtrochanteric osteotomy etc. Even a pseudarthrosis is sometimes acceptable. It is a matter of course that the arthrodesis is the most ideal operation but as soon as the tissue is seriously damaged it cannot be used (see also chapter VI,

E b) and we know nothing about its lasting results. In cases of tuberculosis of the hip joint the extraarticular arthrodesis by means of the bone graft has proved to be very successful as pointed out by KAIPIIS at the International Surgical Congress at Brussels in 1938. The usage of the marrow nail might show similar results but due to the lack of corresponding case material this author has not yet been in a position to perform such an operation. The union obtained by the marrow nail is much stronger and the application of a plaster cast is not required.

For the intra-articular arthrodesis a double nail is indicated just as a Y-nail for the subtrochanteric fracture (see chapter V). The head of the marrow nail for the thigh is quite broad and finds sufficient space in the trochanter massive. That nail has an eye through which a second marrow nail can be inserted which stands in a right angle to the marrow nail which is driven into the marrow cavity of the pubic bone. In the following a detailed description of its application is given:

#### Technique of the marrow nail arthrodesis of the hip joint.

The patient is lying on his back just as in nailings of the neck of the femur. A skin incision 2-3 cm. long and running in the transverse direction is made at the symphysis beginning about 2 cm. laterally from the middle line. The

surface of the pubic bone underneath is bluntly exposed and after that a drill hole is made by means of an electric drill which runs obliquely to the lateral side in the direction of the hip joint. After that the guide rod is inserted into that hole so deeply that it may be palpated underneath the skin over the lateral aspect of the hip joint. From this spot the trochanter massive is widely exposed by means of an incision running in the longitudinal direction. After that the marrow cavity is opened by means of an awl after the guide rod, which is located in the pubic bone, has been somewhat withdrawn. After that the marrow nail is inserted into the drill hole and more or less strong forces must be applied according to circumstances. Just as with Y-nails, also here special attention must be paid to the proper rotation position of the leg (see chapter V, i). With the arthrodesis nail, however, it is much easier to find the right rotation position for the nail because it is precisely indicated by the guide rod of the pubic bone. The thigh nail is inserted so deeply that the tip of the guide rod points to the transverse hole of the nail. It is suitable to remove a part of the exterior wall of the trochanter massive by means of Luer's rongeurs. In this way the insertion of the second nail and the control of the proper position is very much facilitated. The second nail is inserted through the hole of the first nail and in this way it slides over the guide rod into the marrow cavity of the pubic bone. The union obtained in this way is very good because pubic bone nails are very stable.

Example:

The 40 year old patient I.B. suffered a machine gun wounding on 19 July 1944. The left hip bone and the trochanter massive were crushed. Long lasting suppuration.



a                      Illustration 232.                      b  
Pat. I.B. 40 years old.  
a) Pseudarthrosis of the hip joint, fistulating  
for 2 years  
b) after the marrow nail arthrodesis.



A scarcely mobile ne-arthritis in abduction was present, which was only slightly flexible (see illustration 232), but which showed a tendency to increased abduction. Slowly the leg became shorter, which was the indication for the marrow nail arthrodesis. At the time of the operation the patient was free from fever but there was a fistula. The blood sedimentation rate was normal and only slight fever reactions were observed after the operation. Also the pus secretion was only slight and the osteosynthesis was absolutely stable. After a bony healing had been achieved the nail was extracted.

#### 6. The marrow nail arthrodesis of the shoulder joint.

##### Indication:

The stiffening of the shoulder joint in good position results in an excellent usability of the arm if the musculature is intact. Therefore the indication for the arthrodesis may be broad and it corresponds to those already mentioned in connection with the knee joint. In addition one must add the reduction of the relatively frequent contracture of the shoulder in abduction position.

The treatment of old injuries of the upper extremities was dealt with in chapter VI (VI F b). All this is particularly true also for the shoulder joint arthrodesis by means of the marrow nail. The weakened musculature alone is not able to press the bone parts together. On the contrary, due to the weight of the arm they have the tendency to separate.



#### Illustration 233.

Marrow nail for the arthrodesis of the shoulder joint which surrounds the spine in an arch like manner. In order to press the humerus and scapula together either a screw or spiral springs are used.

Consequently when nailing the shoulder joint a special mechanism must be applied to prevent that. Moreover a nailing of this kind is no true nailing because only a small part of the nail is seated in the marrow cavity of the arm above the elbow. The socket alone does not grant sufficient hold because it is very thin and spongy. In old cases it is extremely decayed and may even be missing. Therefore the only stable hold for the nail is the spina scapularis. An operation of this kind was made by this author in 1940. The nail was led along the spina scapularis and attached to it by means of wire after it had been pierced. For this purpose however, this author uses especially shaped nails which are inserted from the medial end of the spine and which surround it in an arch-like manner. In this way an extremely strong hold is guaranteed (see illustration 233).

#### 7. Technique of the marrow nail arthrodesis of the shoulder joint.

The patient is lying on his healthy side. We make an incision 2 cm. long at the medial end of the spina scapularis which runs in the same direction as the spine. After that the medial end is bluntly opened and the spina must be re-opened towards the cranial and caudal direction. In this way the two nail ends which run round the bone can be inserted. After that the shoulder joint is exposed at the posterior plane by means of an arched incision. After the removal of any existing masses of connective tissue and an appropriate treatment of the end of the humerus, the socket is opened in the center by means of an awl and the marrow cavity of the humerus is also opened. Finally over the lateral aspect of the humerus an incision about 2 cm. long must be made in order to facilitate making a drill hole in the humerus for the spiral traction mechanism (see chapter VI, F, b, I). Now everything is set for the insertion of the nail. We begin with the insertion of a wire with a loop on the end through the humerus-drill hole. It must be led through the socket to the incision on the back above the spina. By means of this wire the spring of the spiral traction mechanism is inserted. When using a screw this part of the operation need not be made. After that the nail is inserted from the wound in the back above the spina so that the long end is above the spina and runs through the hole in the socket. We must take care, however, that the hole runs frontwards. We use different nails for the left and right side. When using a wrong nail the nail point points backwards. After that the nail tip is inserted into the marrow cavity of the humerus. It must be driven in so deeply by striking on its head that its curvature touches the spina. After that the spiral spring must be tensed and the incisions closed.

#### Examples:

The 36 year old patient H.A. had suffered an injury of the right shoulder on February 15, 1942. The head of the



arm above the elbow was crushed. Despite several operations, the fistulating suppuration did not subside. The right arm could not be used because all movements with that arm were painful. The shoulder joint was in adduction position. Marrow nailing under Evipan-ether anesthesia as described above. During the operation a wedge was cut out of the articular head. The healing was complicated because of a slight infection with moderate secretion of pus. On September 21, 1945, a sequestrum the size of a bean was removed. The arthrodesis became stable with good position. During the first 4 weeks an abduction splint was used.

As an example of a marrow nailing of a painful ne-arthritis of the shoulder joint I would like to refer to the case of the 44 year old patient A.K. who on 16 March 1945 suffered an injury of the left shoulder which was due to a shell splinter. An infection had occurred due to which the shoulder joint had to be resected (see illustration 234a). Due to the fact that despite several interventions and plaster casts a bony ankylosis was not obtained and because his ne-arthritis was very painful, a marrow nail arthrodesis of the shoulder was made in the above described manner on August 8, 1946. The end of the humerus was freshened obliquely and the wounds came to a good healing (see illustration 234b). A bony ankylosis was obtained which was in good position. The nail was removed 5 months later (see illustration 234c).



a

Illustration 234.

- a) 44 year old patient A.K. Very painful ne-arthritis of the left shoulder
- b) the same case after the marrow nail arthrodesis
- c) the same case after a lapse of 5 months, nail removed (Illustrations b and c see next page).



234b.



234c.

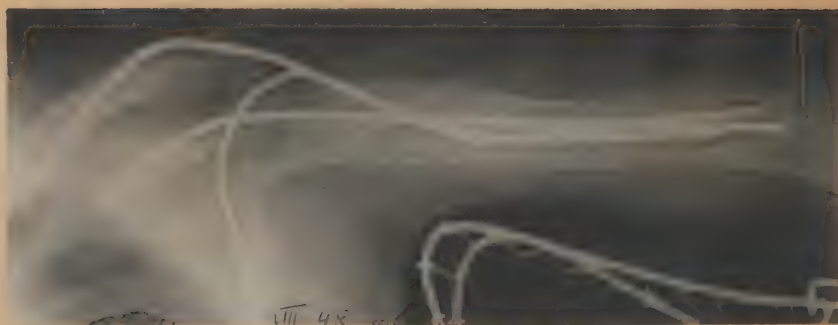
Fortunately there are few cases in which the scapula was destroyed. The patients cannot use their arm at all because of a so-called "flail-arm". In general orthopedic bandages are of no help in cases with that loose a shoulder. During the first World War in cases of this kind it was tried to obtain a certain fixation of the arm by operating the articular head of the arm above the elbow between two ribs.



In such a case in which even the humerus head was missing I tried to obtain a good fixation by using the clavicle. The patient A. E., 30 years old, was wounded on February 16, 1944. Several operations, removal of grafts after abscess incisions. Lues infection on April 24, 1945. The X-ray (see illustration 235a) reveals that the entire scapula no longer exists. We see only the remains of the acromion the size of a walnut. The humerus head is also missing. On July 4, 1946, the shoulder was exposed by an arched incision from behind with the patient under Evipan-anesthesia. After that a thick marrow nail was driven into the humerus which was united with a marrow nail inserted into the clavicle by means of a spiral spring mechanism. Marrow nails driven into the clavicle are rather firmly seated due to the S-shaped curvature of the clavicle contrary to the Kirschner wires which are generally used for fresh clavicular fractures. (See chapter V,3). In this way the arm was firmly suspended (see illustration 235b). In order to replace the scapula two pieces of the fibula of the patient were resected and inserted into the remnants of the shoulder musculature through a stab incision and a hole made with the dressing forceps. After the two pieces had healed in, they were united with the humerus by means of a marrow nail.



a



b

Illustration 235.

- a) Thirty year old patient A.E. Loss of the scapula and head of the humerus due to shell splinters. The acromion is intact.
- b) Fixation of the arm by marrow nailing of the clavicle and humerus which were united by means of a wire.

Mistakes occurring during the marrow nail arthrodesis of the shoulder.

Mistake 1:

After the insertion of the nail the arthrodesis is not stable enough.

Counter Measures:

The spiral spring or the screw must be tensed somewhat more or the marrow nail must be inserted more deeply. If necessary the end of the humerus must be prepared so that it fits the socket better.

Mistake 2:

The arm stands too far in front instead of being slightly angulated to the rear.

Reason:

The nail for the other side was used.

Counter Measures:

An appropriate nail for the corresponding side must be inserted. The nails are shaped in such a way that after a correct insertion the position of the arm is always in abduction and elevation frontwards.

Mistake 3:

After the insertion of the nail the arm is flexible against the shoulder blade.

Reason:

The nail with its two legs was inserted above or below the spina or it is not located in the marrow cavity of the humerus.

Counter Measures:

Insertion of the nail under precise control.

Mistake 4:

The ankylosis is not yet stable after the nail has been extracted.

Reason:

The nail was removed too early.

Counter Measures:

Second insertion of the nail with additional plaster cast if necessary. Kirschner's splitting with the nail in place.

Disadvantages of the marrow nail arthrodesis of the shoulder.

From the technical point of view an operation of this kind is very complicated and it takes a long time, particularly in those cases in which we have to use a spiral spring. This disadvantage, however, will be eliminated as soon as we have nails at our disposal which are better shaped.



### 8. The marrow nail arthrodesis of the elbow joint.

The indications for this kind of an operation are about the same as in the knee joint. It must be pointed out, however, that the elbow joint is most suitable for the arthroplastic (see also chapter IX, 2, A). The marrow nail arthrodesis was successfully used in one case of a fresh comminuted fracture of the elbow.

For the arthrodesis of the elbow, as in the hip, a crossed double nail is used. Both nails are located in the marrow cavity, the one in the humerus, the other in the ulna. After drill holes have been made in the marrow cavities the marrow nail is driven into the humerus and through a slot in it the other is driven into the ulna. Also here either a wire or a spiral spring mechanism is required in order to prevent the separation of the bones (see chapter VI, # I-III). According to the position of the drill hole in the marrow nail in the humerus the elbow joint will become stiff in a right angle or some other angulated position. In any case it seems to be advisable to resect the radius head so that a good pronation and supination is possible.

#### Mistakes with the marrow nail arthrodesis of the elbow.

##### Mistake 1:

The union is loose.

##### Reason:

The spiral spring or the wire were not tensed enough.

##### Counter Measures:

Pulling more tightly.

##### Mistake 2:

The arthrodesis is not stable enough for rotation.

##### Reason:

The nails are too thin.

##### Counter Measures:

Insertion of a second nail beside the thin nail.

##### Mistake 3:

Pronation and supination of the hand is not possible.

##### Reason:

The radius head was not resected or bridge callus or rough connective tissue was formed at the resection site which makes rotation impossible. This is most frequently observed in persons older than 40 years.

##### Counter Measures:

Resection of the head or of the bridge callus (see chapter IX, A).

##### Mistake 4:

Pains in the ulnar side of the wrist.

##### Reason:

After the resection of the radius head the radio-ulnar

joint is painful for about 4-6 weeks.

Counter Measures:

In general pains of this kind subside after some time without any special countermeasures.

Example:

Patient P.K., 49 years old, suffered, on April 15, 1945 a comminuted fracture of the left elbow due to shell splinter. The entire elbow joint and about half of the humerus were missing. (See illustration 236). A profuse suppuration in a 5 cm. long wound on the lateral aspect of the joint was observed. The marrow nailing was made with the patient in this condition. The operation proved to be extremely difficult because the humerus and ulna could not be brought together because of the presence of a connective tissue layer between them, the size of a fist. Due to the fact that the vessels and nerves as well were imbedded there this layer could not be removed. After its separation from the humerus it was pushed forward and after that the two bones could be brought closer together by using strong forces. It can be taken for granted that with a plaster cast the bones could not have been held together. Marrow nailing in the above described way. The union obtained in this way proved to be extremely strong (see illustration 236b). The further course was determined by a long lasting suppuration with the temperatures not considerably increased. As intended the elbow joint came to a bony healing in a right angle position.



a



b

Illustration 236.

Gunshot fracture of the humerus and the elbow joint.

- a) extensive destruction of humerus and elbow joint,
- b) after marrow nailing.



So far marrow nail arthrodeses have not been reported by other authors. In the following I am giving a short survey of the cases treated in the described way:

	number	fatalities	bony healing	no success	result unknown
Knee arthrodesis:					
closed:	11	-	10	-	1
open:	3	-	3	-	-
foot joint:	4	-	4	-	-
shoulder:	7	-	7	-	-
elbow:	2	-	2	-	-
TOTAL:	27	-	26	-	1

The number of cases is much too small to permit a statistical evaluation. The general impression, however, is not bad considering the fact that most of the cases had been treated several times unsuccessfully previously by other surgeons.

In BOEHLER's book, reference is made to two cases in which a surgeon had made a marrow nailing arthrodesis of the acromio-clavicular joint because of a luxation of the acromial end of the clavicle. In both cases the operation was unsuccessful. Despite the application of a Desault bandage the nail had wandered a few days later due to the movements of the arm. Marrow nails for the clavicle show a tendency to wander in both directions and consequently must be secured against that (see also chapter V,g). Moreover, there is the danger that the thin marrow nail for the clavicle cuts through the spongy acromion after some time. In cases of this kind we have not to deal with a true marrow nailing because the nail is not located in the marrow cavity for its entire length. A good result would be obtained only if that part which is lying in the acromion is considerably broadened. As already mentioned above in such a case a bony arthrodesis cannot be expected. The only possibility would be to leave the nail in place persistently or a second operation must be made, as for instance destruction of the acromial end of the clavicle (the acromion cannot be destroyed because otherwise the nail would not find sufficient hold) - or a transplantation of a bone graft must be made.

All this is also true for small joints for any kind of special operation. In cases of this kind the directions given for the large joints must be applied.

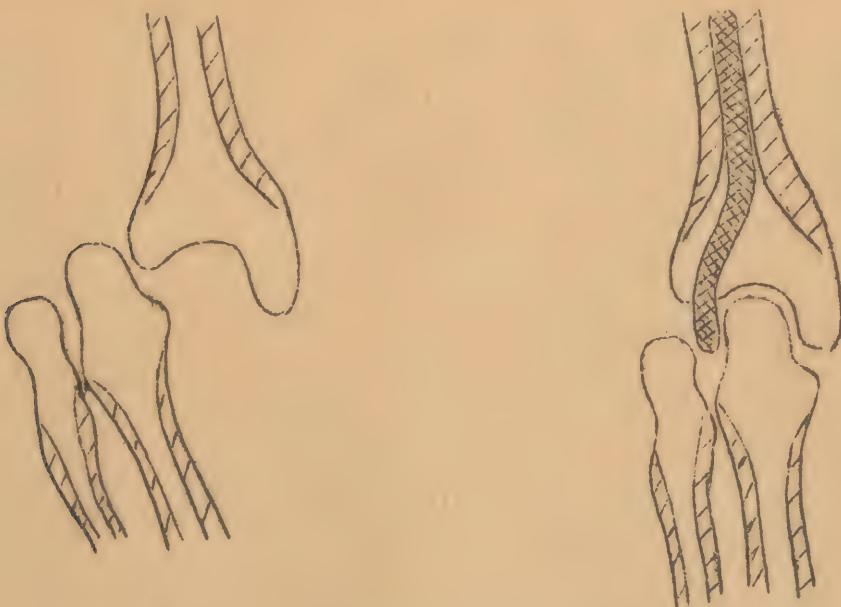
#### Arthrorisis.

The marrow nail may also be used for arthrorisis. The nail must be particularly shaped and thus an opening of the joint can be avoided. A marrow nail is inserted into the

marrow cavity from a place distant from the joint and driven into the direction of the joint. Due to the properly determined site of insertion and the corresponding curvature of the nail the nail protrudes at the desired point of the joint outside the capsule and in this way the flexibility of the joint is limited in this direction. As pointed out above, we must not expect here a bony arthrorisis. The arthrorisis exists only as long as the nail is in place. Consequently the nail must either be kept in the joint for the lifetime of the patient or additional bone must be apposed (large graft or small pieces of bone). In the first case we must take into consideration about the same reflections referred to in the following chapter IX in connection with the arthroplasty by means of the marrow nail. In the latter case a marrow nailing will show good results. A plaster cast is not required and the operation can be made in two stages. Due to the fact that a plaster cast need not be applied the danger of an undesirable further limitation of the flexibility of the joint by stiffening does not exist. The possibilities of excursion of the joint are under constant control.

Marrow nail arthrorises have as far as this author knows, not yet been made by other surgeons and he himself does not dispose of great experience in this particular field. As an example one case of an elbow arthrorisis by means of the marrow nail may be described.

Due to a shell splinter injury the 23 year old patient K.E. had suffered a luxation of the right elbow medially two years previously because the medial part of the humerus was destroyed. Consequently the arm could not be used anymore. Therefore the joint was reduced and without opening the joint a marrow nail was driven into the humerus proximally. The nail was curved so much that it protruded medially beside the joint and prevented the luxation medially. After the operation the patient who was a barber was able to use his arm without pains and impediment of movements.



a                      Illustration 237.                      b  
Marrow nail arthrorisis of the elbow in a  
two year old luxation of the right elbow.  
a) before the operation  
b) after the operation.



## CHAPTER IX.

### Arthroplasty.

Arthroplasty is a special field of surgery in which satisfactory results have not been obtained so far. Only a few specialists have dealt with this special field because the hitherto known plastic operations with precise shaping of the bony joint planes and implantation of fat and fascia and restoration of a joint mechanism required the highest surgical skill. But even those experts are of the opinion that the outcome of such operations is by no means quite sure. Consequently any method which promises a progress in this respect is highly welcomed. It is an obvious development to use marrow nails also in cases of this kind. It must be pointed out, however, that we still lack experience because the number of cases treated in this way is very small. This chapter was added to this publication only in order to leave nothing that is known unsaid regarding this problem. For the time being this chapter is only of theoretical value but nevertheless great hope is attached to it in the future. Only further experiences will prove whether or not these hopes can be fulfilled.

With the arthroplasty the nail has to fulfill two demands at the same time, namely: to render possible the sliding of the bones one against the other, i.e. to form a joint plane and, in the second place it has to take over the task of guiding the movements of the joint in the correct way, which means that it has to be simultaneously a joint mechanism. Furthermore it has to prevent luxation and subluxation as well. The question to which extent the marrow nail can fulfill both demands depends largely on the shape of the nail. This problem seems to be satisfactorily solved in the elbow and hip joint. The main thing, however, is the question of how an artificial joint of this kind will function after a lapse of five or ten years because the nail has to be kept in place for the lifetime of the patient, which is contrary to the marrownailing of fracture and arthrodeses. In a fracture the nail has to stay in the bone for such a period of time as is necessary for the healing of the bone, i.e. long enough until the bone itself is able to fulfill its function again. Immediately after the operation the nail takes over this task of the bone and slowly and gradually the bone redeems these functions in the same proportion as it has regained its strength. The conditions are identical in arthrodesis. With inoperable tumors however, we have often observed that the nail may take over these tasks for the remaining lifetime of the patient. That life, however, is limited to a few years at the best. Thus the conditions are quite different in those cases in which a joint nail must be used in young people and retained in place for their lifetime as a large joint. Therefore plastic surgery by means of the marrow nail depends largely on the material used for the construction of the nails. The question, however, is not the mechanical stability but the chemical properties of the material. The surface of the nail must be chemically so strong that despite strongest friction it can stand the decaying effects of the tissue without any marked reaction. Effects of this kind would hamper the function. There is no doubt that even thin steel is mechanically strong enough and the stainless steel used for the construction of marrow nails is tolerated by the body for a period of several months (see



chapter IV). It is known by experience that marrow nails as well as nails for the neck of the femur are kept in place for years without any noticeable reaction of the body. When such nails have been extracted in many cases no changes of the nails could be observed. There are other cases, however, in which within a few months symptoms of considerable corrosion were noticeable (see chapter IV).

In almost all cases in which two nails were used, signs of corrosion are observed at the spot of contact of those nails and in even those cases in which the nails were made of exactly the same material. It is not true that stainless steel does not corrode at all. Material of this kind develops a thin layer of oxide which prevents further corrosion. At those spots at which this cover is constantly destroyed by friction marked symptoms of corrosion are observed, which, however, must by no means necessarily cause any harmful effect in the patient. This may be proved by the fact that the first Y-shaped nail used by this author and referred to in Chapter V is still in place since 1940, i.e. for 7 years, without causing any harmful effect in the patient. The patient obstinately refuses the extraction of the nail because it does not cause him any trouble at all despite the fact that according to the experiences made so far the nail must be considerably corroded (Y-nails are double nails). From the mechanical point of view a very marked corrosion is of no importance because for a long time the bone has taken over the mechanical function of the nail. With joint nails, however, corrosion considerably endangers the mechanical stability of the joint. We know by experience that the marrow nail as well as the nail for the neck of the femur are surrounded by a connective tissue cover which forms a capsule around the corroded area and in this way protects the other tissue of the body. In this case, however, the nail is firmly seated in this cover whereas in joint nails constant movements take place. Thus conditions are much worse considering the further fact that movements of this kind are made with strong forces.

Thus the problem in question cannot be solved in this way that in both bones of the joint marrow nails are inserted, the heads of which are shaped so that their metal planes slide upon one another. Even when using Akryl or Polivenyl artificial resin as a layer between the two planes cleft-like sinuses would develop which would be filled with liquid and be almost inaccessible to the bacteriocidal reactions of the body. All this was clearly proven by some dog tests in which this author used artificial joints made of V2A steel which were constructed according to the above principles. Artificial resin layers however, had not been used. In those tests both knees of the test dogs were resected at the same time in order to assure that both legs were used at the same time. The heads of two marrow nails had been flattened in such a way that circular disks were formed. These planes were clinched together so that they formed a joint (see illustration 238). A stopping catch prevented the joint from extending too far. After an extensive resection of the joint and of the femur and tibia condyles the two nails were driven into the marrow cavities of the tibia and femur.



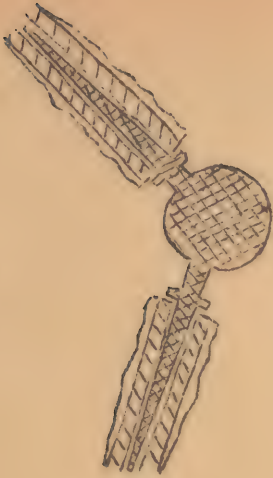


Illustration 238.

Marrow nail arthroplasty in a year old dog. Marked reaction of the periosteum. No success, because two metallic joint planes had been used which rotated one against the other and in this way caused friction.

make the arthroplasty between humerus and ulna. This author resects the radius head as follows: A skin incision about 3 cm. long is made over the lateral aspect of the elbow precisely above the radius head which may easily be palpated underneath the skin. The incision runs in the longitudinal direction (see illustration 239).

After that the surgeon bluntly works his way to the bone. In this way an injury of the radialis is prevented. The head is exposed on both sides with the lig. annulare separated. After that the neck of the radius is separated with a chisel at the transition of the neck to the shaft. In most of the cases the radius neck is split during this process. It must carefully be avoided

that so much is resected that the insertion of the biceps of the tuberositas radii is separated. Otherwise the active mobility of the new joint would be seriously hampered. After that in almost all cases the head of the radius can bluntly be broken out by means of a raspatory because in most of the cases the bony union in the fracture cleft is

This operation was not successful because due to the friction between the two large metallic joint planes the secretion did not subside.

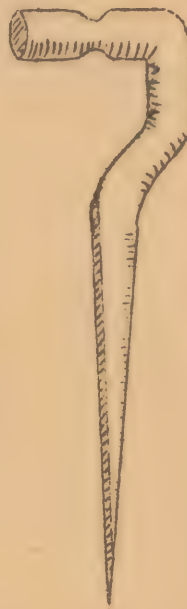
Suitable plastics were obtained only after we had decided to use nails made of one piece of metal. Special attention was paid to obtain a good varnish and its preservation during the insertion process. These nails were thickly wrapped with tissue and sterilized and during the insertion a soft, many folded cloth was laid upon them to protect them against the hammer. The operation itself should be made as small as possible in order to prevent necrosis and too extensive damages to the tissue. In many cases also here a two-stage operation seems to be indicated. In cases of elbow joint operations it will be recommendable to eliminate first the ankylosis between the radius and humerus, i.e. to resect the radius head first and only about 3 weeks later to



Illustration 239.

Skin incision for the resection of the radius head.

not very stable. Any existing bridges in the direction of the ulna must carefully be removed by means of Luer's rongeurs. After that the pronation and supination of the hand must be examined and in doing so we often observe some remnants of the neck. The wound must be sutured in layers and drainage be used for 48 hours. The distal radicular joint is painful in the beginning as already mentioned above. During the second phase of the operation the joint nail must be inserted. It is a cylinder-like joint-roll which is attached to the nail at a right angle. The nail itself has a square cross-section in order to prevent rotation (see illustration 240).



The operation itself is made in the following manner:

At the ulnar side of the joint an incision 10-12 cm. long is made which runs in the longitudinal direction and the bone is exposed on all sides. The periosteum must be kept on the bone. The skin and the soft parts are held aside by raspatories on both sides. The ulnar nerve must particularly be preserved.

Illustration 240.

Arthroplasty marrow nail for the elbow.

The joint can easily be separated by means of a bow saw. Care must be taken however, that the saw cut runs somewhat distally from the former joint cleft so that the joint head of the humerus does not become smaller. After that another  $1\frac{1}{2}$  - 2 cm. of the ulna are resected. In this manner we have obtained a broad joint cleft, which is of great importance. With the arthroplasty it is - according to the experiences made by this author - particularly important that the bones have enough room for action. This can easily be achieved with a marrow nail. Even in those cases in which the joint cleft is very broad the joint will not wobble because it is accurately guided by the nail.

A further disadvantage is the fact that a special covering of the joint planes with fascia is not required. In this way the operation is much simplified and the danger of infection is considerably decreased because any flaps which do not contain vessels are particularly endangered by infection. After that a drill hole is made for the joint of the marrow nail by means of an awl in the middle of the joint-roll of the humerus, which runs through the medial epicondyle and precisely in the direction of the axis of the humerus. In this way the marrow nail can be driven in with a few blows of a hammer. After that the nail is extracted again and then the marrow cavity of the ulna must be opened. At the medial side of that drill hole a small part of the bone must be removed so that in this way the nail can be inserted a little deeper



into the bone substance. In this way it will better withstand rotation. After that the nail is inserted as deeply as possible into the ulna so that the joint pivot stands laterally. After that the joint must be reduced, the joint pivot is inserted into the drill hole of the humerus. For this purpose the end of the ulna is pushed quite medially by means of the nail so far that the pivot stands in front of the drill hole ( see illustration 241). This process requires considerable force. As soon as this position is obtained the pivot is inserted into the drill hole by carefully striking upon the medial end of the pivot. As soon as it is entirely seated in the drill hole the reduction process is finished.

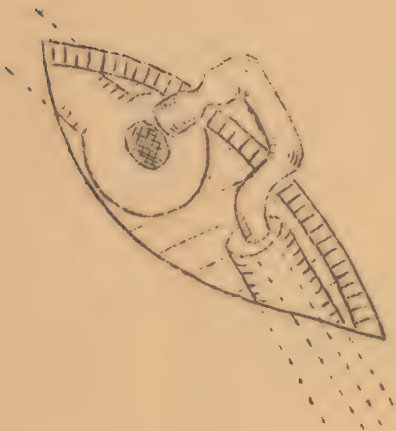


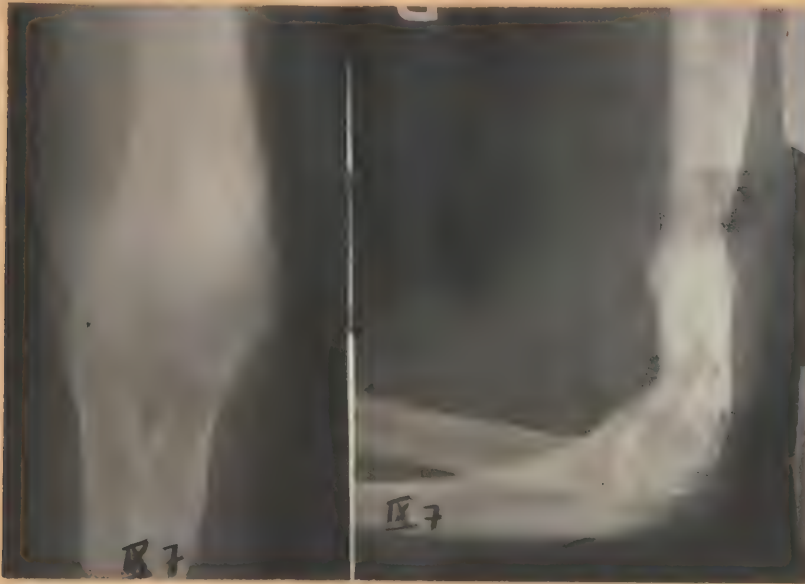
Illustration 241.

Reduction of the marrow nail joint. The marrow nail is already inserted into the ulna. The distal end of the ulna is pushed medially and the joint pivot of the marrow nail was placed in front of the drill hole.

In this way it is absolutely securely guided without lateral wobbling movements, it may be slightly extended and bent. The joint cleft gapes by about  $\frac{1}{2}$  cm. The joint planes must not be carefully filed (polished) so that they fit one another. It will suffice that two roughly separated bone ends are standing in front of each other. The most important thing is that the cleft between them is broad enough. Due to the shearing forces developing during the rotation the joint planes become smooth as demonstrated in the X-ray of the following example. After that the wounds are sutured in layers and a drain is applied for 48 hours. In order to control the danger of infection a wire splint should be applied for the first 8 days. By the time the wounds have healed the joint is held in place by

the connective tissue of the joint. A luxation is possible only in case of a precise lateral displacement amounting to the entire length of the joint pivot of the nail. A displacement of this kind is considerably counteracted by the skin. After either a bony or connective tissue closure was obtained this joint was also held in place by the pressure of the air alone which holds the pivot in the drill hole even in those cases in which a connective tissue encapsulation of the joint mechanism does not exist. We know from anatomy the test with the hip joint. After all soft parts are separated such as the muscles, the sinews, ligaments and the entire joint apparatus of the hip, the leg is held by the pressure of the air, which presses the head into the socket. Only after the insertion of a cannula into the joint cleft does the leg drop down because the air enters the socket through the cannula. Such a joint corresponds to the theoretical considerations mentioned above.

As an example I would like to refer to the case of the 42 year old patient Sch. in which we had to deal with a complete bony ankylosis (see illustration 242a) of the right



a



b



c

Illustration 242.

- a) Bony ankylosis of the right elbow in the 42 year old patient Sch.
- b) after marrow nailing. The joint planes were sawed through in a rough manner. The fracture cleft is wide open. Artificial joint inserted.
- c) after a lapse of 2 months the joint planes have become absolutely smooth.



elbow joint. Marrow nail arthroplasty on August 12, 1946, as described above. The results obtained are demonstrated in illustration 242a -c.

At the end of the operation an almost unlimited pronation and supination as well as flexion and extension of  $60^{\circ}$  -  $150^{\circ}$  was possible. Three weeks postoperative the patient was able to flex and to extend from  $80^{\circ}$  -  $120^{\circ}$ . During the following six weeks a further limitation of flexion by  $10^{\circ}$  was observed. Pronation and supination was no longer possible. The X-ray revealed a bony bridge which extended from the neck of the radius to the ulna and which was removed 10 weeks later by reopening the radius resection incision. At the same time a piece of the neck of the radius was removed. In the beginning the result seemed to be good, but some time later a complete hindering of the pronation and supination was observed again. The flexion extension movements were not hindered. Three months later flexion up to  $80^{\circ}$  and extension up to  $110^{\circ}$  was possible. The arm was in a rotated position and the movements were not painful. The patient used his arm in a quite natural manner and was able to carry loads up to 10 kilograms with his right arm. The guiding of the joint movements was exact. In the tests we made with strong forces no wobbling movements of the joint were observed. The X-rays reveal that the roughly cut joint planes are now absolutely smooth (see illustration 242c). The joint planes are regular rotation planes, the axis of which is the middle line of the joint pivot. This result is the more satisfactory because the patient seemed not to be suited for joint plastics, which is proven by the failure of the resection of the head of the radius and the second resection. The results obtained in these simple operations were very good on an average and a large number of cases was successfully treated in this way. In patients older than 40 years however, absolute failures were frequently observed.

#### Hip joint plastics by means of the marrow nail.

Also in the hip joint a joint nail made of one piece of metal may be used. The nail head is shaped like a ball and the nail is angulated just as the neck of the femur (see illustration 243).

It seems to be risky to use such a large mass of metal but it is my opinion that with regard to Smith-Petersen's good results obtained in hip joint plastics in the manner of a trochanter implantation with a vitallium head put on it, this danger is not too great. The effect of such a metallic body is determined by its surface. The surface of such a hood or such a ball is the same as long as their diameters are the same. The ball forges a stable union with the femur. A straight nail certainly would not be secure against rotation but due to its angulation a nail of that kind is secure against rotation because it is deeply imbedded in the bone of the neck of the femur. In the United States they already have 13 years experience with this special kind of a trochanter joint plastic.



Illustration 243.  
Marrow nail for the hip  
joint plastic.

The technique of the marrow  
nail plastic of the hip.

The hip joint must be opened by means of an incision according to LAMBOTTE, OLLIER, or others. It will be advantageous however, to spare the soft parts as much as possible, keeping the operation as small as possible. This author prefers an incision in the longitudinal direction along the lateral aspect of the thigh which begins above the trochanter. The patient is in a lateral position. The incision must be prolonged in the proximal direction. After having struck off the tip of the trochanter we work our way along the surface of the neck of the femur and in this way we come to the head of the femur. In many cases, however, there is no tip of the trochanter, so that an interference of this kind is superfluous. Later on the tip of the trochanter must be fastened again by means of sutures. The head must be removed by means of a chisel and removed from the socket. If necessary, another socket must be drilled by means of Lexer's drill. After that the neck of the femur is brought closer to the surface of the wound by adducting the leg. In this way it is easy to make a deep groove into the upper (caudal) plane of the neck of the femur which corresponds to the thickness of the nail. This groove runs in the precise direction of the longitudinal axis of the neck of the femur.

Such a groove is most easily made by means of Luer's rongeurs in the corresponding size. After that a hole must be made with an awl into the marrow cavity at the lateral end of the groove. Then the marrow nail is inserted carefully so deeply that it disappears under the level of the groove. For this purpose we use a many folded cloth which is placed over the nail to protect it against the hammer. After that the reduction must be made in much the same way as we usually reduce a normal hip joint. The head must be brought to the posterior margin of the socket and in this way it suddenly slips into it. The wound must be closed by sutures in layers with a drain. After such an operation the movements of the hip joint are normal.

Example of a marrow nail hip plastic.

The 32 year old patient E. R. had suffered a fracture of the left femur. He was run over by a motor car. The head of the femur was broken off precisely at the neck and a fracture cleft ran through the articular head in the transverse



direction. The entire trochanter massive had been broken off and had healed in forward medial displacement. In this way a trochanter implantation was scarcely possible.



a



b

Illustration 244.

- a) Patient E.R., 32 years old. Fracture of the neck of the head of the femur and trochanter massive on the right side.
- b) after the marrow nail hip plastic.

The poor healing result can be explained in such a way that the patient had not had any medical treatment. Since her accident she was confined to bed because she was not able to walk due to the rotation position of her legs. On September 26, 1946, a marrow nail plastic of the socket was performed with the patient under Evipan-anesthesia. The articular head was broken off so that it was not necessary to separate it by means of a chisel. Unfortunately a serious infection of the wound occurred, with a profuse suppuration. For a period of three weeks the patient had temperatures up to 39° C. Her general condition was not seriously involved. A hip plaster cast had not been applied and the drainage subsided slowly without any particular treatment. The wound was closed.

Marrow nail arthroplasty of the fingers.

According to the above described principles R. MAATZ has performed a marrow nail arthroplasty of the basal joint

of the left middle finger which was stiff and in luxation position. After the resection of the joint plane of the phalanx and separation of the sinews from their cicatrizations a marrow nail with an attached joint plane was inserted into the main phalanx (see illustration 245a and b).



a



b

Illustration 245.

Finger joint plastic according to R. MAATZ.

- a) Entirely stiffened luxated main joint of the left middle finger
- b) finger joint plastic according to R. MAATZ. A joint marrow nail was inserted. One half year after the operation.



In this case  $\frac{1}{2}$  year after the operation the finger was freely mobile and painless. This good result is the more amazing, because a complete stiffening of the joint and cicatrization of the flexing tendons had existed.

## CHAPTER X.

### Concluding Remarks.

Finally I would like to deal with the attitude of the patient towards the marrow nailing. In all cases this author obtained the absolute consent of the patients and in none of the cases was it necessary to encourage them for this special kind of operation. In most of the cases the patients fully appreciated the extraordinary measures to be taken, principally those who previously had to be treated with a plaster cast or extension bandage. There are only few people (and most of them are not particularly intelligent) who are not surprised when they are able to walk a few days after the operation after they have suffered a femur fracture. The patient does not see the large size of the instruments which might cause him to be frightened or alarmed. Furthermore he does not know the difficulties encountered with the reduction, etc. What he sees is the surprisingly small wound. He does not suffer from pain, he can move his leg, he does not need a splint. He is not obliged to be confined to bed for months and to lie quietly on his back but he may get up soon, leave the hospital and resume working. He need not be massaged for many months and be subjected to tedious and often painful exercises with his leg. The majority of patients consider all this to be a wonder. Furthermore we must take into consideration that nowadays the patients are not so frightened anymore with regard to an operation. This is particularly true for all those cases in which the patient is brought to the hospital with a bone fracture. He knows for certain that something must be done about his fracture, at least reduction under anesthesia. This may explain why at Kiel where marrow nailings have been performed for 7 years all patients demand to be nailed. They are unhappy if a nailing operation is not indicated for special reasons, as for instance if the fracture is located near the joint or in case of a fracture of the head of the tibia.

The surgeon who wants to perform nailing operations must know that operations of this kind require the highest skill and this difficult art cannot be learned from one of the four manuals mentioned before. Therefore all surgeons who want to get acquainted with this method should frequently see those surgeons who dispose of more experience. It is a matter of fact that all authors have done their best to describe in detail all essential parts of the operation and also the mistakes which are frequently made. We must, however, recognize that only personal experience will lead us to a better understanding of this new method. We have learned by experience that many things which were considered to be understood were not so self-evident to the spectator. It certainly was a great mistake of this author to have presented this new method as an easily performable operation in his first publications.

The marrow nailing operation is a peculiar type of surgery, for which the surgeon must obtain an understanding and become familiarized with. The idea is and must be that immediately such a stable union of the fragments must be ob-



tained that it alone can resist the enormously great strain put on it by the muscles and the dynamic force of the body weight. Furthermore we must know that such a union can be obtained only from the side of the marrow cavity and that the marrow cavity must fulfill this task also in those cases in which a serious infection exists or develops. These are the principles of the marrow nailing operation. It is a matter of course that not all surgeons want to agree with this concept. Therefore I would like to underline once more that the surgeon by no means is supposed to be only a mechanic. All these seemingly purely physical things refer directly to most complicated biological problems and are closely connected with the most difficult processes of the living organism. All this was dealt with in detail in chapter III.

It seems to be a matter of course that for mechanical operations of this kind a particularly adequate armamentarium is required. This author however, understands rather well the desire of many surgeons who are ambitious to perform all customary operations with a few simple instruments if possible. This author is furthermore convinced that it is wrong to use special instruments for each single operation which in general cannot be used for any other operation. With the marrow nail operation, however, the situation is quite different. Nobody will be astonished to see that a motor car repair shop has plenty and many kinds of tools for the repair work of a car. But in much the same way also the very complicated system of the human skeleton requires a complicated armamentarium and marrow nailings should not be made if such an armamentarium is not available. This author knows of many cases in which the surgeon decided to perform a nailing operation after he had happened to get a marrow nail. In another case a surgeon extracted a marrow nail without having at his disposal any special instrument for that purpose. The result was, that he opened the femur laterally, which caused the death of the patient by shock. The marrow nailing operation should therefore be made only if a complete armamentarium is available and only by those surgeons who are well acquainted with this new method. Only then can we speak of a progress obtained by the nailing operation. It is intended that this book will prove to be a contribution to that progress.

LITERATURE.  
-----

- ACKERMANN, W. Ein kombiniertes Einschlag- und Zieh-  
geraet fuer Marknaegel, Der Chirurg,  
H. 3-6, S. 93-94, 1944
- BADE and KUENTSCHER Wirkungen von Roentgenstrahlen auf den  
Knochen (experimentelle Untersuchungen  
an Hunden) Zbl. f. Chirurgie, 1940.
- BAUER, K. Marknagelung oder Drahtextension?  
Zbl. f. Chir. Nr. 7.
- BOEHNER, Joerg Marknagelung und Kugelkallus, Zbl.  
f. Chir. 1943
- BOEHNER - JESCHKE Operative Behandlung der Schenkelhals-  
brueche und Schenkelhalspseudarthrosen  
(Verlag Maudrich, Wien, 1938)
- BOEHLER, Lorenz Der schaedliche Einfluss von Aehsen-  
knickungen auf die Gelenke des Beines  
Der Chirurg, H. 4, 1942.
- BOEHLER, Lorenz Zur Behandlung der Querbrueche mit  
der Marknagelung. Zbl. f. Chir. # 31,  
1942.
- BOEHLER, Lorenz Vorschlag zur Marknagelung nach  
Kuentscher bei frischen Oberschenkel-  
schussbruechen (Der Chirurg, H.1, 1943)
- BOEHLER, Lorenz Apparate fuer die Marknagelung nach  
Kuentscher, Der Chirurg, H. 2, 1943.
- BOEHLER, Lorenz Die Technik der Knochenbruchbehandlung  
im Frieden und im Kriege (Verlag Wilh.  
Maudrich, Wien).
- BOEHLER, Lorenz Zschr. f. Orth. u. ihre Grenzgebiete,  
4. Bd., 2. H. 1943
- BOEHLER, Lorenz Vorschlaege zur Knochenkuerzung bei  
Nervendefektschuessen, Der Deutsche  
Militaerarzt 1943.
- BOEHLER, Lorenz Behandlung d. Pseudarthrosen mit dem  
Marknagel von Kuentscher. Zbl. f.  
Orthop. B. 75, H. 1, 1944.
- BRUECKE Ein unangenehmer Zwischenfall bei der  
Marknagelung des Oberschenkels, Zbl.  
f. Chir. # 11, 1943.
- BURKLE de la CAMP, Die Marknagelung der Pseudarthrose.  
Kongress der Rheinisch-Westfaelischen  
Chirurgen, April 1947, Bochum
- BORDASCH Dtsch.Z.Chir. 253, 1940.



- BLECK Die normale und gestoerte Knochenbruch-  
behandlung. Neue deutsche Chir. Bd.62,  
1940.
- BOERMA Arch.klin.Chir. 176, 1933, 666.
- CELLARIUS, Th. Die Marknagelung bei Pseudarthrosen  
Zschr.f.Orth. u.ihre Grenzgebiete,  
74.Bd. 2. H. 1943.
- CELLARIUS, Th. Ueber die Marknagelung von Pseudar-  
throsen. Zbl. f. Chir. # 21, 1943.
- CORNIOLEZ, C.-E. L'osteosynthese des os longs, Un  
volume, chez Doin 1931
- DANIS, R. Communication personelle
- EHALT Die offenen Brueche der langen Roehren-  
knochen, ihre Behandlung und Ergebnisse.  
Verlag Maudrich, Wien, 1938.
- EHALT Mschr. Unfallheilk. 1940, 387.
- EHALT Erfahrungen mit der Marknagelung nach  
Kuentscher. Zbl. f.Chir.# 47, 1942.
- EHALT Vorweisung ueber die Marknagelung bei  
Knochenbruechen. Zschr. f.Orth. u.ihre  
Grenzgebiete, 74.Bd. 2. H. 1943.
- EHRlich, W. Unsere Erfahrungen mit der Marknagelung  
nach Kuentscher. Zbl. f. Chir. # 30, 1941.
- EHRlich, W. Bisherige Ergebnisse unserer operativen  
Knochenbruchbehandlung unter besonderer  
Beruecksichtigung des Kuentschernagels.  
Arch.f.orth.u.Unfall-Chir. 42.B.3.H.1943.
- EHRlich, W. Zschr. f. Orth. u.ihre Grenzgeb. 74.Bd.  
2. H. 1943.
- EIGENTHALER Behandlung einer Pseudarthrose des Ober-  
schenkels mit der Marknagelung nach  
Kuentscher. Zschr. f. Orth. u.ihre Grenz-  
geb. 74. Bd. 2. H. 1943.
- ERB Dtsch.Z.Chir. 218, 1925.
- FISCHER, A. W. Diskussion zu Kuentscher. Arch.f.  
klin.Chir. 200.Bd. Chir.Kongress 1940.
- FISCHER A.W. and R. MAATZ Weitere Erfahrungen mit der Marknagelung  
nach Kuentscher. Arch.f.klin.  
Chir. 4. H.203.Bd. 1943.
- FISCHER, A.W. and REICH Wie steht es um die Gefahr der Osteo-  
myelitis bei der Kuentscher-Nagelung  
offener Frakturen. Zbl. f. Chir. Nr.  
8, 1943.

- GEBHARDT Zschr. f. Orth. u. ihre Grenzgebiete, 74. Bd. 2. H. 1943.
- GEHL Die Marknagelung nach Kuentscher, dargestellt an einem ausgewählten Fall. Mschr. f. Unfallheilk. H. 12, 49 Jg. 1942.
- GERHARDT Erfahrungen mit der Markbolzung. Zbl. f. Chir. No. 47, 1942.
- GERHARDT Einige Faelle von Markbolzung. Zschr. f. Orth. u. ihre Grenzgeb. 74. Bd. 2. H. 1943.
- GOMEZ Indicaciones y tecnica del clavaje medular por los Marknagelungen. Verlag Manuel Marin, Barcelona 1942.
- GREIFENSTEIN and E. RIX Marburger Sitzungsberichte, 3, 64, 1929.
- GREIFENSTEINER H. (Amberg, Oberpfalz) Kuentschernagelung od. Doppeldrahtspannbuegel-Osteosynthese bei falscher Gelenkbildung m. 2 Textabb. Krieglach, 19 Nov 1914
- GUENTZ, Ed. Die Anwendung der Marknagelung nach Kuentscher bei orthop. Knochenoperationen.
- GUETTNER Erfahrungen und Ergebnisse der Marknagelungen. W.kl.W.Nr. 46, 1943.
- GUETTNER Marknagelung bei Pseudarthrosen
- GUETTNER Ueber unsere Erfahrungen mit der Marknagelung bei Knochenbruechen. Zschr. f. Orth. u. ihre Grenzgeb. 74. Bd. 2. H. 1943.
- GUETTNER Schwere Komplikationen und Eiterungen bei der Marknagelung.
- HAASE, W. Der Kuentschernagel bei Spontanfraktur durch Hypernephrom Metastase. Zbl. f. Chir. B. 70, Nr. 35, 1943.
- HAASE, W. Marknagelung bei Knochengeschwulst Zbl. f. Chir. # 2, 1943.
- HAASE, W. and G. RICHTER Arch. orthop. Chir. 36, 541, 1936.
- HAEBLER, C. Die Indikation zur stabilen Osteosynthese. Mschr. f. Unfallheilk. 7. H. 50 Jg. 1943.
- HAEBLER, C. Die "Stabile Osteosynthese" der Knochenbrueche und ihre wirtschaftliche Bedeutung. Zbl. f. Chir. # 11, 1943.



- HAEBLER, C. Die Marknagelung der Oberarmbrueche vom proximalen Ende. Zbl. f.Chir. # 21, 1943.
- HAEBLER, C. Die Marknagelung bei verhaltenen Schussbruechen. Zbl. f.Chir. Nr. 47, 1943.
- HAEBLER, C. Die Marknagelung in der Wiederherstellungschirurgie.
- HAEBLER, C. Einrichtungsgeraet f.d.Marknagelung. Der Chir. H. 3-6, S.91-93, 1944.
- HART Schwierigkeiten u. Verwicklungen bei der Marknagelung von Knochenbruechen. Zbl. f. Chir. # 28, 1943.
- HEIM, H. Die Marknagelung der langen Roehrenknochen nach Kuentscher. Der deutsche Militaerarzt, H. 3, 1943.
- HEIM, H. Marknagelung von Oberschenkelschussfrakturen. Der Chir. Nr. 13, S.387-393, 1943.
- HEIM, H. Erfahrungen mit der Marknagelung. Chirurgenkongress, Berlin, 1947.
- HERZOG Hebelgeraet zum Ausgleich der Seitenverschiebung bei Bruechen der langen Roehrenknochen zur Anwendung bei der Marknagelung. Zbl. f.Chir.# 11, 1943.
- HERZOG Verbessertes eigenes Hebelgeraet zum Ausgleich der Seitenverschiebung bei Bruechen der langen Roehrenknochen zur Anwendung bei der Marknagelung. Zbl. f. Chir. Nr. 46, 1943.
- HERZOG Klinische Erfahrungen mit der Oberschenkelmarknagelung nach Kuentscher. Deutsche Zschr.f.Chir. 5 u. 6. H.1943.
- HUSTIN, A. Osteosynthèse par plaques "géantes" dans le traitement des fractures et des pseudarthroses de la diaphyse fé-morale. Le Scalpel, t.94, No.17, pp. 1020-1025, 1941.
- JEANNENEY et  
MAGENDIE L'enclouage centromédullaire des fractures diaphysaires des os longs par tiges d'acier (méthode de Kuentscher). Mém.Acad. de Chirurgie, v. 70 nos 9-11, 1944.
- JOLY Communication personnelle 1945.
- JUNGE, H. Die Marknagelung bei Tumoren  
Chirurg, 1941 .
- KIRSCHNER Erfahrungen mit der Marknagelung.
- KILIAN, H. Erfahrungen mit der Marknagelung.
- KOENIG Die Chirurgie der Knochenbrueche, Berlin, 1931.

- KOENIG . Aussprache zu Kuentscher (Arch.f. klin.Chir.200.Bd. Chirurgenkongress 1940).
- KOESTLER Zschr. f. Orth.u.ihre Grenzgeb. 74.Bd. 2. H. 1943
- KROMPECHER Anat.Anz. 1934,78; 1936, 81.
- KUENTSCHER, G. Die Darstellung des Kraftflusses im Knochen. Zbl. f. Chir. 61.Jg. # 37, 1934.
- KUENTSCHER, G. Ueber den Nachweis von Spannungspitzen am menschlichen Knochengeruest (Morphologisches Jahrbuch 75, 427-444, 1935, Leipzig.)
- KUENTSCHER, G. Die Spannungsverteilung am Schenkelhals. Arch.f.klin.Chir. 185.B. 2. H. 1936, Berlin.
- KUENTSCHER, G. Ueber das Wesen der mechanisch bedingten Knochen- und Gelenkerkrankungen. Arch.f.klin.Chir.Kongressband 1938, Berlin
- KUENTSCHER, G. Ueberlastungsschaeden am Knochensystem. Med.Klinik Nr. 29, 1939.
- KUENTSCHER, G. Die Marknagelung von Knochenbruechen. Klin.Wochenschr. # 1, S.6-10, Jg.19, 1940.
- KUENTSCHER, G. Die Marknagelung von Knochenbruechen. Arch. Klin.Chir. 200.B. Chirurgenkongress 1940.
- KUENTSCHER, G. Die Technik der Marknagelung des Oberschenkels. Zbl. f.Chir.1940, # 25.
- KUENTSCHER, G. Ein Hochfrequenzverfahren zum Auffinden von Metallfremdkoerpern. Zbl. f. Chir. 67.Jg. # 50, 1940.
- KUENTSCHER, G. Kallus ohne Knochenbruch. Zbl.f.Chir. 68.Jg. # 19, 1941.
- KUENTSCHER, G. Die Technik der Marknagelung des Unterschenkels und Oberarms. Zbl.f.Chir. 1941, # 25.
- KUENTSCHER, G. Das Wesen der Marknagelung von Knochenbruechen. Zbl. f.Chir. 69.Jg. # 47, 1942.
- KUENTSCHER, G. Die stabile Osteosynthese bei der Osteotomie. Der Chirurg, 14.Jg. 1942, H. 6.
- KUENTSCHER, G. Die Marknagelung bei Knochenbruechen. Zschr.f.Orth.u.ihre Grenzgebiete, 74. Bd., H. 2, 1943.
- KUENTSCHER, G. Ueber die Marknagelung unter besonderer Beruecksichtigung der Kriegschirurgie. Zbl. f.Chir. # 47, 1943.



- LAMBOTTE, A. La chirurgie opératoire des fractures, 1913.
- LAMBOTTE, A. L'ostéosynthèse par clouage transarticulaire dans les fractures juxta-articulaires. Paris Chirurgical, pp. 145-148, 1925.
- LAMBOTTE, A. Contribution à la chirurgie conservatrice de la main dans les traumatismes. Livre jubilaire du Prof. J. Verhoogen, 1929.
- LAMBOTTE, A. Le clouage transarticulaire en ostéosynthèse. Technique Chirurgicale, # 2, 1935.
- LAMBOTTE, A. Communication personnelle, 1945.
- LAMBRIDUNI, C. Intramedullary Kirschner Wires in the treatment of fractures. Proceed. Roy. Soc. Med. v.33, # 3, pp. 153-157, 1940.
- LEVEUF, J.A. A propos de L'enchevillement central par broche dans le traitement des fractures de la clavicule. Mém. Acad. Chirurgie, v.70, # 9, p. 100, 1944.
- LINSMAYER Einstellgeraet fuer die Marknagelung. Zschr.f.Orth.u.ihre Grenzgebiete, H.2. 1943.
- LINSMAYER Ein Geraet fuer die Marknagelung nach Kuentscher. Der Chirurg, H.2., 1943.
- LOOSER Schweiz.med.Wschr. 58, 125.
- MAATZ, R. Erfahrungen der Kieler Klinik bei der Marknagelung von Knochenbruechen. Zschr.f.Orth.u.ihre Grenzgeb. 2.H.1943.
- MAATZ, R. and A. W. FISCHER Weitere Erfahrungen mit der Marknagelung von Kuentscher. Arch.f.klin. Chir. 4.H. 203.Bd. 1943.
- MAATZ R. and A. W. FISCHER Die chemische Reizwirkung des Kuentscher Nagels. Arch.f.Orth.u.Unfall Chir. v. 42, # 4, 1943.
- MAATZ R. and A. W. FISCHER Die Bedeutung der Fettembolie bei der Marknagelung nach Kuentscher. Zbl. f.Chir. # 11, 1943.
- MAATZ R., and REICH Formschluessigkeit und Kinematik bei der Kuentschernagelung. Zbl.f.Chir.# 35, 1943.
- MAATZ, R. Schraubung der Kahnbeinpseudarthrose. Zbl.f.Chir.B.70, # 48, 1943.
- MAATZ R. Ueber den Verlauf der Knocheninfektion und-regeneration nach Marknagelung geschlossener und offener Schaftbrueche sowie Osteotomien. Bruhn's Beitrag z.klin.Chir. Bd. 147, 1943.

- MAATZ, R. Die Kuentscher-Nagelung des Unterarmes. Der Chirurg, Heft 9, 1943.
- MAATZ, R. Die Kuentscher-Nagelung der Unterarmfraktur. Zschr.d.Chir. 74.Bd.H.9,1943.
- MAATZ, R. Bruhn's Beitr. 174, 358, 1943.
- MATTI Arch. orthop.Chir. 31, H.2, Zbl.Chir. 1936, # 25.
- MICHEL-BRECHET et GODARD Le Brochage central amovible des fractures de l'avant-bras, de l'humerus et du tibia. Mem.Acad.de Chirurgie, v.70, # 9, 1944.
- MONDOR, H. et NARDI, C. Prothese metallique intratibiale pour fractures de jambe. Mém.Acad.de Chir. v. 68, # 22-23, pp.326-327, 1942.
- MUELLER-MEERNACH Zbl.Chir. 60, # 29, 1933.
- MUELLER-MEERNACH Zbl. Chir. 1942, # 7.
- NEUMANN, F. L'os purum dans l'enchevillement des fractures diaphysaires. Bull.Acad.de Chir. v. 63, # 11 p.431, 1937.
- NORDMANN Zbl. Chir. 1940, 825.
- NORDMANN Kongr.d.deutschen Ges.f.Chir.Berlin, 1940.
- PFEIFER, J. Ein neues Instrument zum Herausschlagen des Marknagels, Zbl. f.Chir. # 46, 1943.
- PASCHER, M. Die Marknagelung bei Bruechen der langen Roehrenknochen. Med.Klin.Wschr. f.prakt.Aerzte, # 8, 1943.
- PASCHER, M. Med.Klin. 1943, 8.
- PASCHER, M. Marknagelung offener, infizierter Knochenbrueche auch im Stadium der Sepsis? Zbl.f.Chir. 71.Jg. # 31/32, 1944.
- PAUWELS, F. Der Schenkelhalsbruch, ein mechanisches Problem. Stuttgart, Ferd.Enke, 1935.
- RAISCH Wien.med.Ges. Juli 1942.
- RAISCH Experimenteller Beitrag zur Frage der Osteosynthese mit besonderer Beruecksichtigung der Marknagelung nach Kuentscher (Bruhn's Beitrage zur klinischen Chirurgie, B. 175,1944.)
- RAISCH Zbl. Chir. 1943, 390.



- ROCHER, CH. L'enclouage centromédullaire des os longs. Mem.Acad. Chir.v.70, # 9, p.104, 1944.
- ROCHER, CH. L'enclouage centromédullaire des os longs. La Presse Medicale # 8, 1945.
- RUSH, I-V, et  
RUSH, H-L. A technic for longitudinal pin fixation of certain fractures of the ulna and of femur. Journal of Bone and Joint Surg. # 3, 1939.
- SCANZONI, C. Ueber Komplikationen und ihre Ursachen bei der Marknagelung nach Kuentscher. Zbl. f. Chir. # 28, 1943.
- SINN, H.D. Ueber die Bedeutung der mechanischen Ursachen der Pseudarthrosen. Zbl. f. Chir. # 18, 1937.
- SIANY, A. Marknagelung und Blutbild. Arch.f. orth. u.Unfall-Chirurgie, l. H. 1944.
- SOEUR, R. L'enclouage médullaire des fractures diaphysaires du fémur. Le Scalpel, # 15, août 1944.
- SOEUR, R. Intramedullary pinning of diaphyseal fractures. Bone a. Joint Surg.# 2, 1946.
- SOEUR, R. L'Ostéosynthèse au clou. Masson et Cie, Paris.
- SPRENGELL Zbl. Chir. # 7, 1942.
- SCHNEIDER, E. Die Marknagelung in der Unfallchirurgie Der Chir. # 15, 1943.
- STOTZ, W. Unsere Erfahrungen mit der Marknagelung nach Kuentscher. Arch.f.Orth.u.Unfall Chirurgie, # 3, 1943.
- STRACHER, O. Marknagelung, Zbl. f.Orth. # 2, 1942.
- STOR, O. Ueber ein Instrument zum Ziehen der Knochennaegel nach Kuentscher. Zbl. f. Chir. # 21, 1943.
- STOR, O. Erfahrungen mit der Marknagelung nach Kuentscher. Der Chir. # 11, 1943.
- VOGE, A. Die Marknagelung in der Wiederherstellungschirurgie. Zbl. f.Chir. # 46, 1943.
- WAGNER Zur Marknagelung der Knochenbrueche. Zbl. f.Chir. # 35, 1943.
- WALTERHOEFER and  
SCHRAMM Arch.klin.Chir.118, 794 (1921); 119, 768 (1922).

- WATSON - JONES                      Fractures and joint injuries. V.II.  
chez Livingstone 1944.
- WITTMOSER                            Zschr.f.Orth.u.ihre Grenzgeb. 74.Bd.  
2.H. 1943.
- WITTMOSER                            Einstellgeraet f.d.Marknagelung.  
Der Chir. 2.H. 1943.
- WESTERBORN A.                        Nailing in the marrow cavity in cases  
of recent fractures and pseudarthroses.  
Acta Chir.Scandin. # 2, 1944.
- ZIELKE                                Die Osteosynthese der Oberarmhals-  
brueche. Zbl.f.Chir. # 21, 1943.
- ZOTTL                                 Einstellgeraet nach Boehler f.Ober-  
und Unterschenkel-Marknagelung.  
Zschr.f.Orth.u.ihre Grenzgeb. 74.Bd.  
2. H. 1943.



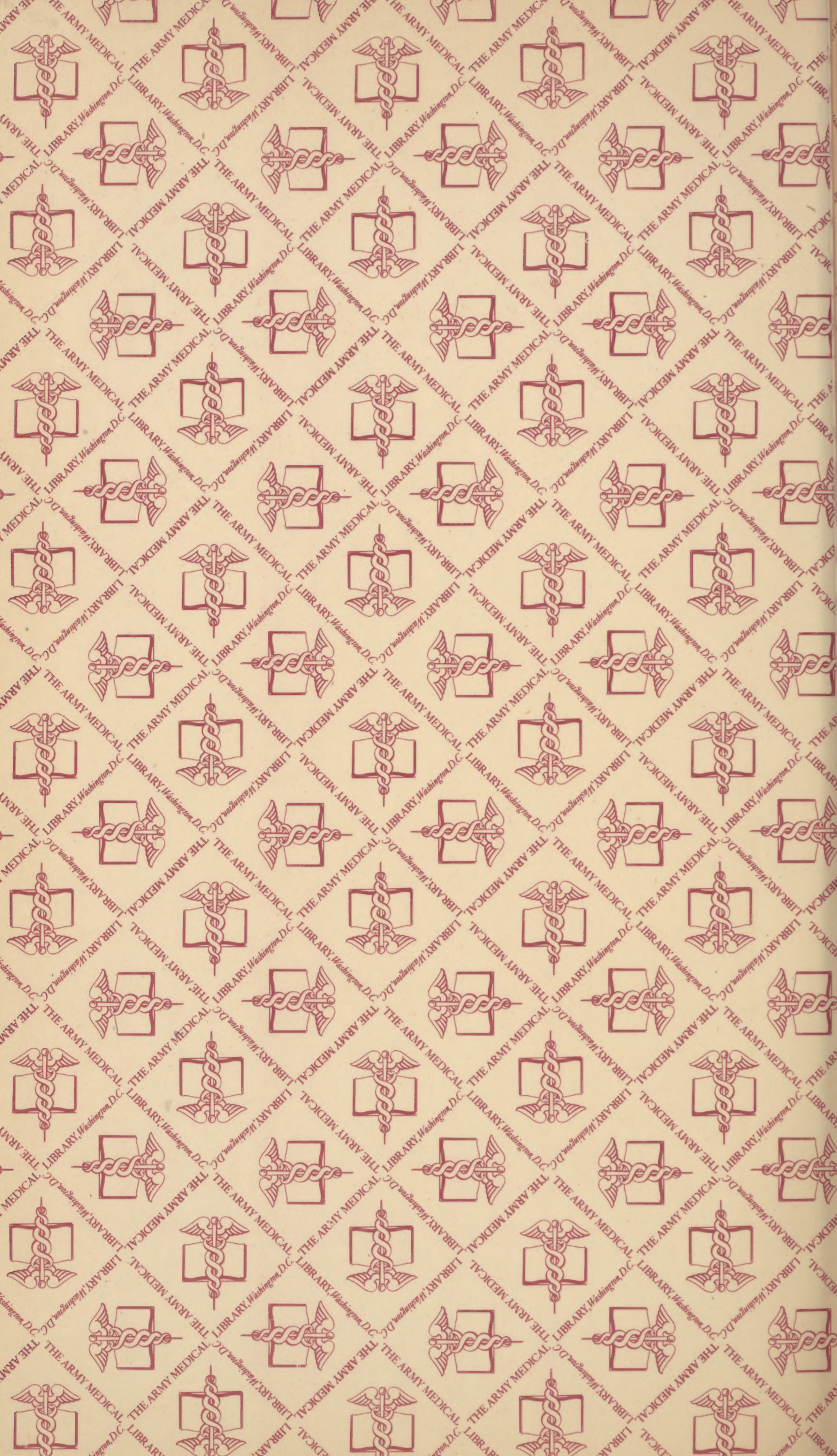




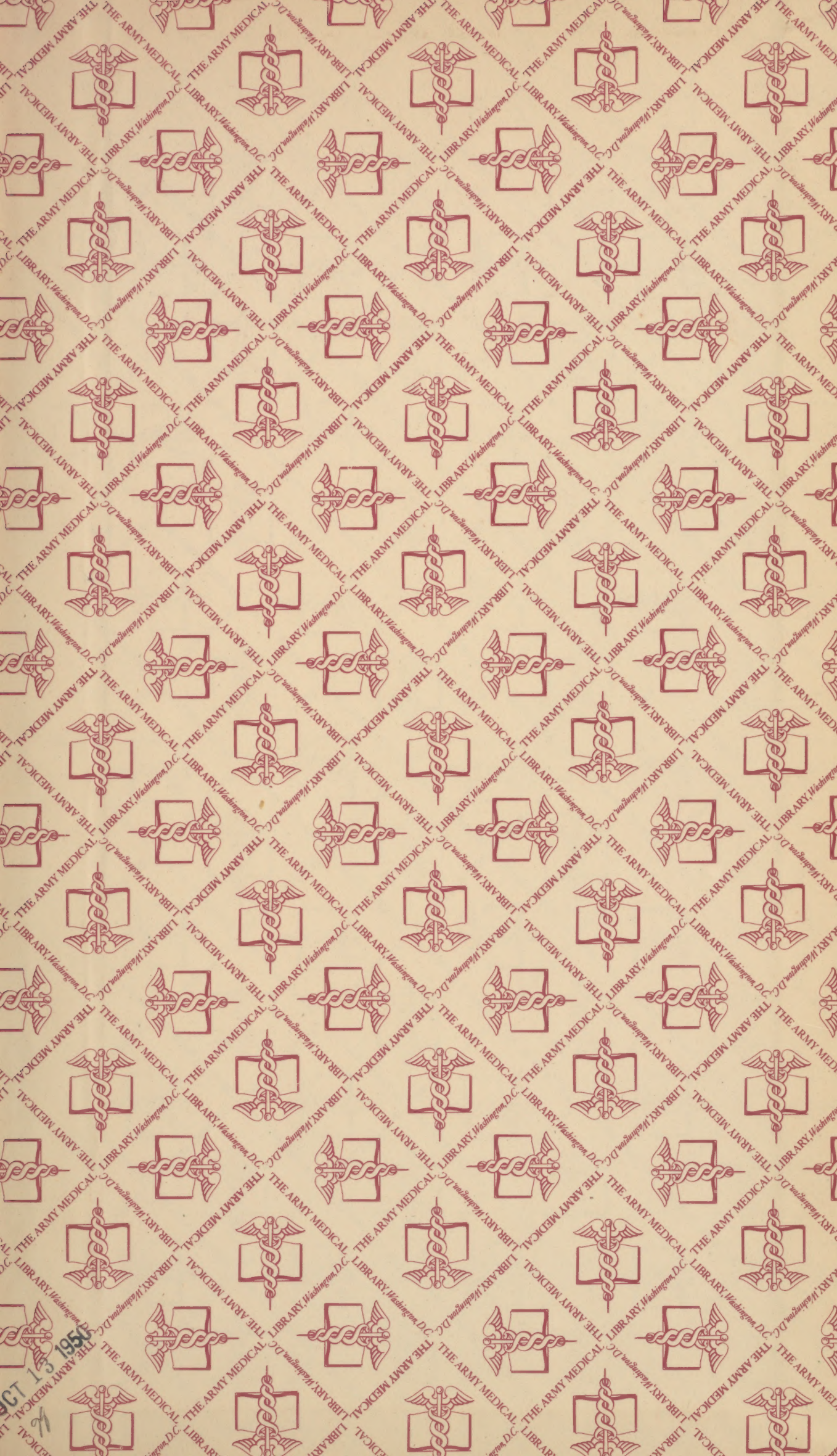






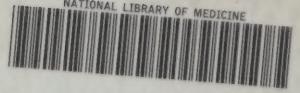








NATIONAL LIBRARY OF MEDICINE



NLM 00072709 3